JULY, 1958

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a quick look at WORLD OIL this month

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8853

BUSY OIL MEN: To help you put first things first, scan these time-saving digests on this and the following pages, checking ☑ those you want to read first.

CURRENT OUTLOOK

☐ **Two excellent harbingers** of renewed drilling activity in the Denver Julesburg Basin: New exploration programs are increasing—multi-well programs, surest sign of a healthy basin, are again in evidence. For complete details on current basin activity, plus a close look at the reasons for the sharp increase in activity, turn to **New discoveries boost activity in Denver Julesburg** ... **Page 62**

☐ **With the recession as a strong stimulus,** other industries are taking steps to streamline their operations. The oil industry should be doing the same. For several timely suggestions as to what drillers, producers, regulatory agencies and royalty owners can do to cure many of the industry's economic ills, turn to **Page 63. Rising costs can be curbed** ... **E. B. Miller, Jr.**

☐ **The U. S. oil industry purchased** $1.1 billion worth of equipment, materials and equipment during 1957—a new record, according to the latest biennial U. S. government study. Complete details are given on this highly informative report, including a breakdown of total purchases in four major oil areas—plus trends in oil industry use of principal materials. **Oil industry purchases at record high** ... **Page 65.**

Turn the Page ▸

Why you shouldn't miss the International

WORLD OIL'S expanded International Outlook Issue, scheduled for publication August 15, will contain . . .

Two large-scale, (40 by 28 inches) multi-colored wall maps suitable for framing.

One map will cover the Middle Eastern areas of oil interest; the second will cover Venezuela, Colombia, Ecuador, Peru, Bolivia and Trinidad.

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The annual International Outlook Issue is designed to furnish every oil man—whether in the U. S. or abroad—complete, authoritative coverage of all oil operations in every country where oil is sought and/or produced.

Because this special issue acquaints them with developments which affect their companies' future, as well as their own pocketbooks, the International Outlook Issue is valuable reading to management in every phase, to drilling and production foremen, drilling and production engineers and superintendents, drilling contractors, oil men in every phase of exploration, and to crew members in all capacities.

Much of the information—its accuracy is a trademark of the issue—is furnished by oil companies and governments. WORLD OIL's own staff joins with a large number of correspondents located at strategic spots throughout the world to supply the remainder.

This issue has wide appeal to:

U. S. subscribers

because the U. S. Mid-Year Forecast and Review, including revised figures on U. S. drilling program for 1958, has a direct bearing on the welfare and plans of every U. S. oil man . . . and because over-

Continued from Page 3

☐ **Demands for helium** by industry and the government are rapidly outpacing the supply. However, strong steps are being taken to correct this situation—steps that may mean extra profits for the natural gas industry. For details on plans to tighten present helium conservation policies, plus a close look at the over-all U. S. helium picture, see **U. S. moves to increase helium supply** . . . . . **Page 66**

EXPLORATION

☐ **A theory of primary migration** is proposed to explain an occurrence in the Pedernales region of northeastern Venezuela. Detailed geochemical studies have shown that oil is starting to accumulate in a sand trap 5,000 years old there. See **Page 79. Oil migration in Recent sediments** . . . . . **A. L. Kidwell and J. M. Hunt**

☐ **A bright oil future for Wyoming** is presaged by new concepts in geological thinking. The belief that oil and gas accumulations could be found only on the anticlines has been disproved as new fields have been developed in other types of traps. Operators have proved that most of the productive oil sands in Wyoming are not necessarily blanket-type sands without pinchouts or permeability changes. Permeable rocks at depths below 8,000 feet have been proven, and this should stimulate deeper drilling. See **Page 83. Wyoming oil prospects are good** . . . . . **Dr. Horace D. Thomas**

DRILLING

☐ **The principles of hydrodynamic studies** in relation to petroleum exploration and basic data required for such studies are discussed on **Page 90.** Drill stem testing has been found to be one of the better methods of obtaining the most sensitive informa-

Outlook issue . . .

seas oil developments always have made their impact felt in this country . . . and because information on other oil areas could directly concern U. S. oil men, since they—sometime—may become engaged in overseas operations, either with their own company or another company.

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tion required—that of formation fluid pressures. Special emphasis is placed on the accuracy of pressures in describing the tools of formation testing. Ways of improving the accuracy of pressure measurements and the interpretation of such information are suggested. **Application of the DST to hydrodynamic studies.**

Dr. H. K. van Poollen and Sam J. Bateman

☐ **Extensive research into pump operation** with various type muds and under various conditions, both normal and abnormal, has provided data that the author has analyzed to help the man in the field obtain higher efficiency from the mud pumps. In this first of a series of articles, the author acquaints the operator with the main parts of the pump system and explains the theory of pump operation. The series starts on **Page 100. Know your mud pump—it can save you money.**

Samuel L. Collier

☐ **One of the most perplexing problems** to confront the driller is formation water shut-off to allow air and gas drilling. Numerous experiments, both in the laboratory and the field are being carried out to overcome this impediment to increased drilling rates. Here is an article that explains one of the experiments being carried out; the proper application of two solutions containing water soluble inorganic material that will form a precipitate in the interconnected pore spaces of the reservoir rocks and thus reduce permeability. See **Page 105. Can formation water be shut off for air drilling?** . . . . . **Othar Kiel**

PRODUCTION

☐ **Maximum profits from a pattern water-flood** project in primary depleted or near depleted fields requires careful development planning. For a thorough discussion of factors influencing an optimum flood project see **Page 112. Optimum water-flood development** . . . . . **Bert Murphy**

☐ **Fresh water can be a successful fracturing treatment** under certain conditions. Where applicable, it can reduce substantially the cost of such treatments. Data are presented on the first 100 fresh water fracturing treatments in the Permian Basin, and a description of how the techniques operate is described on **Page 117. Fresh water fracturing can cut treatment costs** . . . . . **R. E. Hurst, J. T. Rollins and H. A. Stewart**

☐ **Determine the water content of natural gases** at pressures to 10,000 psia and temperatures from —60° F. to 300° F. with this chart. A correction chart is also included to account for natural gases for various gravities. A third part of the chart will enable corrections to be made for the salinity of the brine with which the natural gas may have been in contact. Instructions for its use are presented for the chart prepared by **Dr. John J. McKetta** and **Albert H. Wehe** . . . . . **Page 122**

☐ **What are the advantages and disadvantages of hydraulic fracturing** for increased secondary recovery? A survey, conducted among fracturing ex-

perts in almost every state with secondary recovery operations, indicates approximately 80 percent of the producing wells have an improved rate of recovery with a reasonable payout time after fracture treatment. The success on injection wells has been even higher with better sweep efficiencies and reduced flood-out time. Turn to **Page 126. Fracturing can help secondary recovery**.....**Dr. E. T. Guerrero**

☐ **Despite early wasteful producing practices,** operators in the North Homer field of Louisiana expect to ultimately recover 63 million barrels of oil or 61 percent of the original oil in place. Over 25 percent of this ultimate recovery is attributed to gas repressuring and closely controlled production practices. For a comprehensive field case history of this secondary recovery project, turn to **Page 134. Gas repressuring methods successful in North Homer field, La.**

Paul R. Waddle

☐ **Experimental data on bubble behavior** have given a better understanding in the correlation of laboratory and field reservoir performance. The importance of bubble formation in reservoirs is that their number determines the departure from equilibrium in the reservoir and may substantially modify the relative permeability ratio of gas to oil and therefore the oil recovery in gas-drive fields. High production rates are the only known practical means to change this number. See **Page 129. Does bubble formation affect reservoir performance?**.....**Denton R. Wieland**

☐ **Proper use of saturation pressure** in evaluating new oil reservoirs can aid in planning an efficient drilling program. An excellent article for your production file is on **Page 144. Saturation pressure—a reservoir evaluation tool**.....**Frank W. Cole**

INTERNATIONAL

☐ **The first discovery of gas in East Pakistan** was made in mid-1955 when Pakistan Petroleum Ltd. Sylhet 1 cratered and caught fire, destroying the rig. Sylhet 2, drilled down-structure, was completed in mid-1956, confirming existence of a commercial gas deposit. Sylhet 3 has now been completed, providing a reserve of about 200 billion cubic feet of recoverable gas. An 8-inch pipe line is to be built to transport the gas to industrial markets 145 miles southwest of Sylhet to Dacca. Turn to **Page 154. Outlook good for East Pakistan gas field**.....**Walter Sekules**

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Indexed by Industrial Arts Index and Engineering Index

Looking Ahead . . .

More Crude in July . . . Suez-created surplus crude stocks are finally approaching reasonable levels. Summer increase in demand is on the way. Result: Texas Railroad Commission eased the reins a little, ruled nine-day allowables for July—an increase of 121,745 barrels per day over June. New total: 2,604,798 barrels daily.

Situation is also expected to improve in other prorated states. Unprorated areas will continue to pick up crude markets prorated operators are losing because of tight allowable schedules.

Look for Business Upswing . . . Bureau of Mines predicts July demand for U. S. crude will average 6.97 million barrels daily, 105,000 barrels per day over the June level.

Looking farther ahead, IPAA forecasts third quarter total crude demand (including imports) at 8.6 million barrels daily, about the same as last year. Market for domestic crude will average about 7 million barrels per day, compared with 7.1 million barrels during same period in '56.

Another healthy sign: Crude and product stocks at end of May were about 12 million barrels under year-ago levels, were expected to be 45 million barrels under June '57 at beginning of this month.

Record Activity in Rocky Mountain States . . . Prospects for renewed crude demand are spurring Rocky Mountain operators to step up their search for new oil and gas reserves. A record 141 new locations for oil and gas wells were staked during second week of June, including 94 development wells and 46 wildcats.

A good example is Denver Julesburg Basin where both majors and independents are breaking out new exploratory programs. (See Page 60). Big reason for renewed interest: Continued success in Nebraska side of the Basin.

Smaller Operators Drill 4 Out of 5 Wells . . . World Oil study of 22 major oil companies shows they drilled 11,078 wells in the U. S. last year—20.8 percent of national total of 53,350 wells. *Smaller companies* drilled remaining 79.2 percent of total, compared with 79 percent in '56. Majors drilled only half the wells in only four of the 24 oil producing states—South Louisiana, Utah, North Dakota and California.

Quick Look at Washington . . . Predictions are that Alexandria, Va., price-fixing trial of 29 oil companies may not get underway until '59, then will drag out for many months (See Editorial, Page 59); there is a chance the case may result in some Justice Department civil suits . . . *Look for more antitrust investigations* of nearly every segment of the industry . . . *IPAA predicts natural gas producers will be freed* from utility-type controls next year; reason: biggest enemy of Harris Bill, the coal industry, has come to terms with gas transmission companies . . . *Despite rising sentiment in the Senate* against placing import curbs in bill to extend reciprocal trade program, the oil industry will make strong bid to nail Ikard-type amendment to the bill in committee and will also push amendment on Senate floor; though far from overflowing, there is still optimism in some quarters that import curbs will win out.

$23.5 Million to Arrest Subsidence . . . Principals in California's Wilmington oil fields soon will start crash program to stop tendency of land to sink downward around Long Beach. Plan is designed to halt immediately any further pressure decline in affected area, and to restore original reservoir pressures in five years. 710 million barrels of water will be injected into the oil fields at rate of 390,000 barrels per day for first five years.

Good Wells Make Good News

A Monthly Report of Successful Well Treatments

July, 1958

For over-all fracturing economy—including first cost, time of payout, rate of decline, and frequency of workovers—it will pay you to consider Dowell's fracturing services. Here are some recent studies of Dowell fracturing results:

- **Beaver County, Oklahoma.** (New Gas Well) Completed through perforations into the Hoover formation, 4420 to 4467 feet, this well came in natural with a potential of 4190 mcfd. The well was broken down and treated with 500 gallons Mud Acid, followed by 500 gallons Dowell acid with demulsifying and silicate control agents added. This increased potential production to 6360 mcfd. Then the well was fractured with Petrojel*, using 30,000 gallons of gelled crude with 80,000 pounds of sand plus F.L.A.* (Fluid Loss Additive). The average injection rate was 54.2 bpm. After treatment and clean-up, the well was given a four point test which showed an *open flow potential of 126 mmcfd.*

- **Christian County, Illinois.** (New Oil Well) This well was completed open hole in the Silurian dolomite from 1910 feet to 1921 feet. Since this was known to be a problem reservoir, the operator had formation samples tested. He found that the formation reacted twice as fast with intensified acid as it did with regular acid. Accordingly, he ordered Acid Petrofrac* with Dowell's intensifying agent added. 7000 gallons of acid-oil emulsion and 7000 pounds of sand were used. Freflo* in oil and 500 gallons Dowell Silicate Control Acid preceded the Acid Petrofrac. *After the well returned the load oil, the sustained production was 15 boph.*

- **Hot Springs County, Wyoming.** (Old Oil Well) This well was completed open hole, 3495 to 3562 feet, in the Phosphoria lime. This dense formation has some natural fractures and minor effective vugs. Before treatment, production had declined to 8 bopd. Operator ordered Acid Petrofrac, using 5000 gallons acid-oil emulsion and 5000 pounds sand. F.L.A. was added to the fracturing fluid to help extend the fractures and the drainage area of the well. Treatment was performed down tubing at 9 bpm. *45 days after treatment well was producing 70 bpd with two per cent water.*

- **Harrison County, East Texas.** (Old Oil Well) This well, completed through perforations into the Travis Peak sand, 6272 to 6276 feet, had declined to 25 bopd. Operator wanted to stimulate potential so he could get full allowable for eight-day production. Petrojel was selected, using 5000 gallons gelled crude with 5000 pounds sand. Injection was down tubing at 8 bpm. *After treatment settled production was 273 bopd.*

You have an intimate knowledge of *your* production problems and *your* well's characteristics. Likewise, your Dowell engineer knows what each of the many Dowell fracturing services is designed to do. He will work closely with you to help you get the most from a stimulation treatment. For service call any of the 165 Dowell service points and offices. In Canada, contact Dowell of Canada, Ltd.; in Venezuela, contact United Oilwell Service. Or write Dowell, Tulsa 1, Oklahoma.

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Destroying Ourselves

THE RECENT INDICTMENT of 29 oil companies for price conspiracy is another example of the growing tendency in the U. S. to harass and cripple business for temporary political gain.

When the Suez Canal blockade shut off Middle East oil shipments to Western Europe, President Eisenhower asked U. S. oil companies to do everything within their power to provide enough oil to keep our Western Europe allies from freezing and to keep factories and transportation systems operating.

Oil companies rose to the occasion in admirable fashion. They used such expensive extremes as moving pipe line pumps, reversing pipe line flow and circuitous routing, even shipping oil overland from West Texas to St. Louis, then down the Mississippi River to the Gulf of Mexico. At one time shipments from the U. S. to Western Europe reached a million barrels daily. The result was that Western Europe experienced little inconvenience.

In "gratitude" for this magnificent effort, the U. S. government has proceeded to inspire a grand jury indictment against 29 oil companies on the ground that "beginning sometime in 1956 and continuing through January, 1957, the 29 oil companies engaged in an unlawful combination and conspiracy to raise, fix and stabilize the prices of crude oil and automotive gasoline."

THE INDICTMENT DELIBERATELY IGNORES the basic laws of supply and demand under a free business economy. Otherwise, the charges never would have been filed.

Total demand for U. S. oil rose from 8.7 million barrels per day in September, 1956, to 11.4 million barrels in January, 1957. During this period, export shipments to Western Europe rose from 350,000 barrels per day to slightly more than 1 million barrels daily.

It is natural under a free business economy for prices to fluctuate with sharp increases or decreases in demand. And, that is just what oil prices did.

Wholesale cargo prices for regular gasoline along the Gulf Coast averaged 10 cents per gallon in late 1956. During the peak of the European lift in early 1957, these prices averaged 11.1 cents per gallon. Crude oil prices rose 25 to 35 cents a barrel. (This was the first substantial increase in crude oil and gasoline prices since 1953, although cost of materials and labor had resulted in sharp gains in operating costs).

The grand jury conveniently did not extend its investigation beyond January, 1957. Demand for U. S. oils dropped sharply following reopening of the Suez Canal to Middle East oil shipments. And, the wholesale gasoline price in the Gulf Coast fell to 9.9 cents per gallon by February, 1958—less than it was before the Suez crisis.

THIS INDICTMENT of 29 U. S. oil companies on such unreasonable grounds fits the now familiar "kick business on the shins" political philosophy like a glove. (Incidentally, two of the companies indicted are involved in litigation in Iraq for cutting Iraq crude prices 5 cents a barrel in 1956.)

Such attacks on business are becoming all too common in the U. S. Unless checked, they are sure to soften the American free enterprise business system for the socialistic kill. This can mean only one thing: the destruction of the whole American way of life.

This and similar actions (the Memphis decision, control of producer gas prices, and several recent oil industry Congressional investigations) are contrary to the American way of life in that they:

1. Place party politics above maintaining a healthy national economy.

2. Fail to recognize that prices are based on supply and demand under the American business system.

3. Ignore the need for business to earn a profit, and thereby attract investment funds with which to continue to expand and create additional jobs for this country's growing population.

4. Studiously ignore the inflationary increases in postwar material and labor costs.

5. Constantly harass industry with investigations, criminal charges, and crippling legislation until progress is out of the question.

6. Rip industry apart in the eyes of the public.

OUR ELECTED POLITICIANS should be able to find constructive things to do in these trying times. Surely, they do not need to be destructive, which is what they are doing when they continually kick the business system that has contributed so much toward making this country outstanding in the history of the world.

Warren L. Baker

There won't be another 1949-1956 "drilling boom," but operations stand a good chance to approach the rates of earlier days as . . .

New discoveries boost activity in Denver Julesburg

THINGS ARE looking up again in the Denver Julesburg Basin.

Both majors and independents are breaking out new exploration programs throughout eastern Colorado and western Nebraska. There is scattered exploration to zones previously passed up in several more or less local areas of the basin. Presently, more is being said about possible production above the established D and J sands of the Cretaceous Dakota, but there is still confidence in some deeper (Permian) prospects.

Multi-well programs, the surest sign of the basin in health, are back in evidence. At least 12 have been drilled or announced since the year began. Some of the more significant developments:

- Most important series this year in Colorado was a three-well Morgan County program by Williamson, Kissinger & Co., Denver independent. One of the three was a 13 million cubic feet-per-day gas discovery. Another was completed for 940 barrels of oil per day, opening up a new field which has been the most active spot in Colorado this year.
- Biggest of recent Denver Julesburg series was the Dawson Oil, Brinkerhoff Drilling and J. L. Cramer drilling program in Washington County, Colorado. Beginning late in 1957, these operators drilled 25 wells. Two discoveries resulted.
- British-American Oil Producing has two series for Logan County. One is a five-well program—the other calls for seven wells.
- Davis Oil drilled a six-well wildcat program on farmout from Pan American in Yuma, Kit Carson, Lincoln and Washington counties.
- Beaird, Burke and Pexoil have completed a pair of Morgan County wildcats and plan additional work.
- Shawnee Oil has an 8-10-well series in the Dune ridge area, Logan County.
- In western Nebraska, Sunburst Petroleum is drilling an 18-well program, including eight wildcats in Scotts Bluff, Banner and Kimball counties.
- Other Nebraska programs are a six-well series by Shell Oil in Scotts Bluff County, and a five-well series by Colorado Southern Petroleum in northern Banner County.
- Tom Vessels, Jr., and Strain Drilling are at work on a five-well wildcat program in Washington and Weld counties. Kimbark Co. has a 13 to 15 well series coming up in Arapahoe, Adams and Washington counties.

Hottest Denver Julesburg areas. The hottest place in the basin at the moment is the Bijou-West Bijou area of Morgan County (See Map). These two fields were found by the successful two wells in the three-well series by Williamson-Kissinger & Co. The West Bijou discovery flowed 940 barrels of oil per day from a six-foot section of D sand. The first offset, drilled by British-American Oil Producing, flowed 42 barrels per hour. Later results were mixed.

Ten producers have been completed in the field, but a half dozen dry holes have also been drilled. The field is apparently delineated to the south, and in part to the east.

The Bijou gas discovery, in 8-4n-59w, has not been offset. Production is from D sand. Interest has been concentrated in West Bijou. However, early in May, Thames & Turnbull, Denver, completed a D sand discovery in 5-4n-60w for a flow of more than 900 barrels of crude per day. Thus, a 20-square-mile area east and north of the West Bijou field has two excellent producers, but has had almost no other drilling.

A west extension to the Thames & Turnbull discovery was drilled by Gulf Oil at 1 Price-Persons, c se ne 6-4n-59w. It was completed early in June for a flow of 1,055 bbls. of oil per day on three quarter inch choke from a 10 ft. perforated zone in D sand.

The Gulf gage may well be called phenomenal in the Denver Julesburg Basin. By the time this west extension was completed Gulf was busy at a southwest extension. Meanwhile, British-American began tests of an indicated success south and east of the pool opener. It has not yet promised more than a commercial well, and is apparently not of the caliber of the Gulf extension.

Early June found three apparent discoveries testing in Kimball County alone. Wyoming Western Oil swabbed 21 bbls. of oil per hour at 1 Benziger-A, c nw ne 1-14n-58w, a mile and a half northwest of Gehrke field, and toward the western limits of production in Kimball County. An offset has already shown for production.

In southern Kimball County, Nebraska, British-American Oil Producing recently completed a 900 barrel-per-day discovery in 10-12n-56w.

Production is from J sand. This well has been offset by four different operators, and three of the four were successful—a performance far above par in the Denver Julesburg.

This discovery, known as the Allchin field, is a mile northeast of Ansel field, one of the better small pools discovered in Nebraska during the past three years.

Shortly after completion of the Allchin discovery, a wildcat a mile and a quarter southwest of Ansel showed for production with a very good recovery of oil on drillstem test of J sand. Braden Drilling, operator of this discovery, completed it for 293 barrels per day.

These are the most significant recent discoveries in the more active basin area. They are of a caliber which in the past has proved adequate to attract new activity very rapidly.

Activity in outlying areas. On the west side of the basin, some interest has been shown in the Hygiene sand series above the D and J members of Dakota. Production was found in this formation in the New Windsor area, where California Company is active in Permian production. At least one series of exploratory wells has been announced with a test of the Hygiene as the primary objective.

Increased drilling in the Denver Julesburg Basin has created a density of about one well for each six square miles. However, in the more active areas, the local density is higher. Thus, additional attention is being paid to more outlying areas.

Why activity is increasing. Eight important factors are behind the renewal of intense activity in the basin:

1. Continued success in Nebraska has led to renewed operator confidence in Colorado.

2. The success ratio for exploratory wells went up in 1957.

3. During the next two years, the Denver Julesburg will be deluged with lease expirations. Since it is almost axiomatic that a lease in the basin must be drilled to be safely dropped, it is fairly certain that farmouts will become easier to get—and primary leaseholder activity will increase.

4. It has become increasingly apparent that even with the Denver Julesburg's almost 70 percent stratigraphic trap reservoirs, payouts are quick.

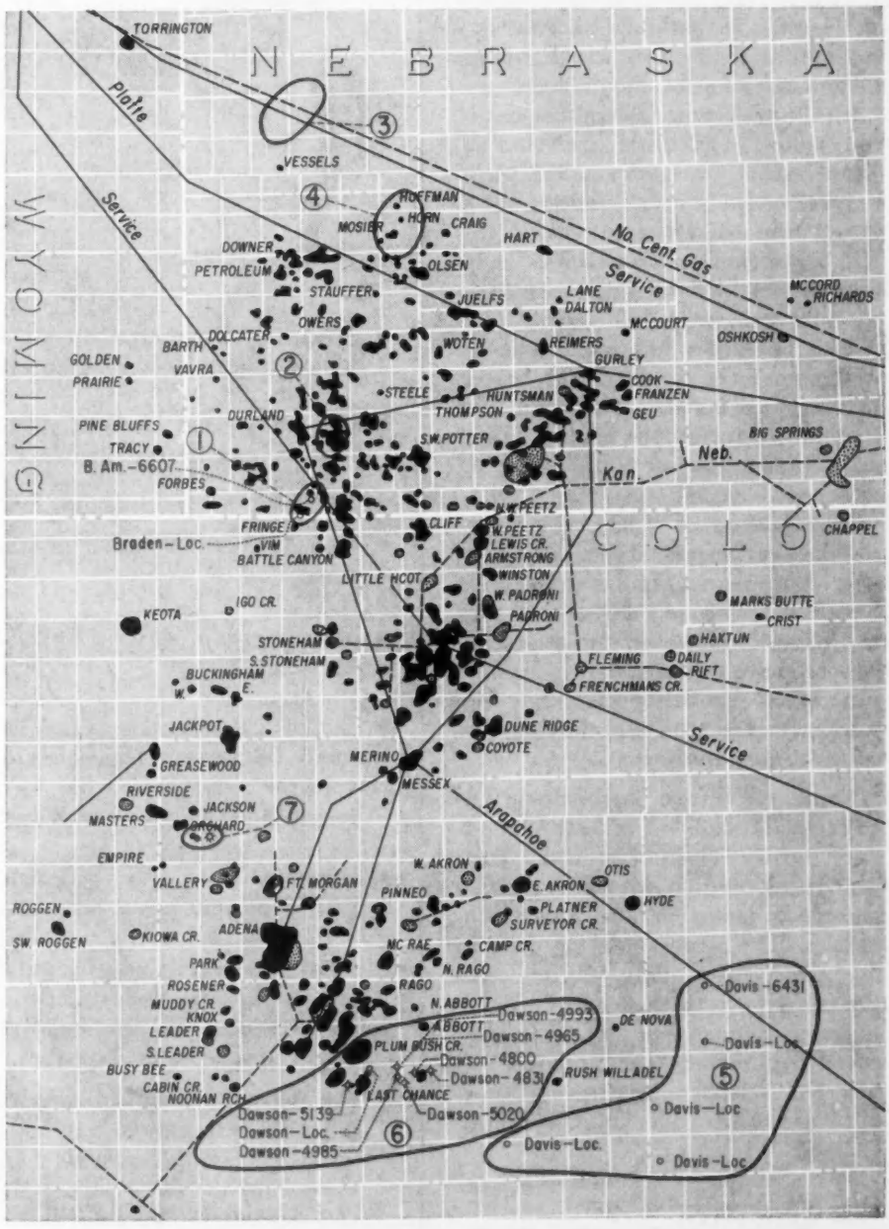
5. Many geologists still maintain that not half the sizable fields in the basin have been found.

6. Statistical control is readily available.

7. Present crude production limits, about 65 barrels per day per well by pipe line take, is beginning to look good in comparison with other areas.

8. Despite all that has been said about the spotty success of drilling in the Denver Julesburg, drilling cost per barrel of oil is fairly good. To date, including a high percentage of failures, each barrel of Denver Julesburg Basin oil has been found at a drilling cost of a little more than 90 cents.

Because of the lease situation, availability of farmouts, and relatively low drilling costs—all strong attractions for independents—there is good rea-



Seven Areas of Current Activity in the Denver Julesburg Basin

Legend: (1) British American's recently completed 900 barrels-per-day crude discovery started the Allchin field, one mile northeast of Ansel field. Braden Drilling wildcat discovery, shown as a location, has good production shows—is 1¼ miles southwest of Ansel. (2) Sloss field, with 7,000 barrels per day production, is main reason why Pan American was leading driller in Nebraska last year, with 141 wells completed. (3) and (4) Most recent Nebraska programs to be announced are a six-well series by Shell Oil in Scotts Bluff County and a five-well series by Colorado Southern in northern Banner County. (5) Davis Oil drilled a six-well wildcat program on farmout from Pan American in Yuma, Kit Carson, Lincoln and Washington counties. (6) Biggest of recent Denver Julesburg series was Dawson Oil, Brinkerhoff Drilling and J. L. Cramer program in Washington County, Colorado. Operators drilled 25 wells, with two discoveries. (7) Hottest place in the basin at the moment is Bijou-West Bijou area of Morgan County, Colorado. Ten producers were completed through first week in May, with six dry holes.

son to believe many more multi-well programs will make their appearance shortly.

Sloss field—key to Nebraska activity. Although activity began to decline in the basin after 1955, the Nebraska portion showed a gain of more than 90 percent in drilling compared with the previous year. It has held to that level, while the bulk of the decline has registered in the Colorado basin area. Not since Adena, still the basin's largest field, has a very substantial field been found in the Colorado sector of the basin.

In the meantime, several important discoveries were made in Nebraska. Most notable of these was Sloss field. A more or less routine "Denver Julesburg" type discovery opened this Kimball County pool in 1954. Development was a little slow—mostly in the past two and a half years.

The field now has more than 80 wells, produces about 7,000 barrels per day. It is the principal reason why Pan American was the leading driller in Nebraska during 1957, with 141 wells completed.

Sloss is the best of several substantial discoveries in Nebraska during the past four years. Similar new fields have not been found during that time in Colorado. However, recent activity has brought discoveries which hold promise of similar pools. Only development will tell—and development seems to be forthcoming.

Look for more secondary recovery. The advent of active secondary recovery operations in the Denver Julesburg Basin has recently become a factor in long range economics. The water-flood at Adena field, Morgan County, Colorado, is the best known of these.

Pan American has recently proposed flooding of Sloss and Kimball fields in Nebraska—and several projects are underway in Cheyenne County, Nebraska.

Water supply is a major secondary recovery problem in the basin. In some instances sewer outflow is purchased from basin cities to purify and recover the water for reservoir flooding.

Ultimate primary recovery for fields in the basin's most heavily drilled area is estimated at about 280 million barrels. A secondary recovery of about 40 to 50 percent of this total would be a very sizable economic plus.

—The End

If Oil Could Speak

If oil could speak it would have many fascinating truths to tell the non-oil public—truths that would win thousands of new friends for the oil industry.

But, oil can't speak—you can. You, as an individual, can win many new friends for the oil industry if you will pass the true facts on to your non-oil industry friends.

Here are some of those true facts. They are being presented for one purpose: To keep you posted on your industry, so you can tell the story oil is unable to relate.

Read these facts. You will find them informative—and interesting.

- Efficient, oil-powered diesels are saving the railroads 700 million dollars a year, according to one railroad industry spokesman.
- Swimming pools made of glass-cloth-reinforced polyester resin, an oil product, can be installed in four days for less than the cost of an automobile.
- A single tankship load of gasoline would run your car for five hundred years.
- Average cost of all wells drilled below 15,000 feet runs about $617,000 per well.
- Out of 250,000 wells drilled in the U. S. during the past five years, nearly 38 percent have been dry holes. This means the production from the average well has to carry the cost of two-thirds of a dry hole in addition to its own costs.
- Out of millions of acres leased in the search for oil annually, only 5 to 10 percent prove productive.
- Although the oil industry earnings have not been out of line with earnings in other industries, the requirements for heavy reinvestment has prevented distribution of earnings to shareholders in the same proportions as other industries.

  The Department of Commerce reports that for the five years 1944-47 industrial corporations paid out in dividends about 41 percent of their net income, while larger oil companies paid out slightly more than 35 percent for the same period. In 1954, the corresponding figures were 52.9 percent for manufacturing companies and 42.7 percent for oil companies.
- Net income of other industries have averaged more than the oil industry in four out of nine years (1946-54). For the 9-year average, the profits as a percent of net worth of the oil companies exceeded other industries by only one percentage point. In view of the high risks in oil production, it is not unreasonable to expect that the rate of return on the cost of successful properties should be somewhat greater than on investments involving less risk.

Rising costs can be curbed!

Because of the recession, other industries are taking definite action to improve their economic status. Oil operators should do the same.

By E. B. Miller, Jr.
Vice President, General Manager Southern Division
Tidewater Oil Company, Houston

THE CURRENT recession is motivating other industries to cut costs by streamlining their operations. Why not oil?

Now is an ideal time for drillers, producers, regulators and royalty owners to take stock of past practices to see where improvements can be made and affirmatively step forward to make them effective. Now is the time for each segment of drilling and production to ask the question, "How can we develop and produce oil and gas reserves as economically as we know how?" Then, do something about it.

Improvements in drilling technique are helping materially to accomplish this objective. A good job is being done in lowering drilling costs, particularly when the difficulties associated with deeper drilling are taken into consideration.

The combined efforts of manufacturers, drilling research and related industries are resulting in an improved penetration rate. The important thing is that a free exchange of these developments exists and is applied by the industry soon after they are demonstrated to be effective.

But, what about production? It is obvious that a sound producing segment is essential to the economic well-being of the drilling segment.

Failure to recognize, at least to some degree, that domestic production is in competition with the world supply of oil, is far from realistic. Just as unrealistic is the failure to recognize that cost goes hand in hand with competition. If the oil industry is to improve its competitive position with imports and other fuels, such "failures" must be erased. Each operator and royalty owner must assume the responsibility of producing oil as economically as he knows how, without creating physical waste.

The same is true for state regulatory agencies. Many of the economic hardships experienced by the U. S. oil industry today result from inadequate and unrealistic state regulations and laws. The most glaring of these "weaknesses" are to be found in present policies regarding well spacing, unitization, onshore and offshore proration—and regulations covering completion, measuring and operating methods.

Well spacing and unitization. When 26 wells are drilled on 13 acres (this happened recently), it must be concluded that economic waste has taken place, not for the individual, perhaps, but certainly for the industry. When an application is made for a permit to drill an 11,000-foot gas well on five acres, economic waste is going to take place.

When it is necessary to install separate facilities for measuring oil and gas on each individual property, when proved equipment for a centralized system could have been installed for half the cost, it is obvious that the oil industry is not operating as efficiently as it could.

Every one of these expenditures which does not add to the recovery from the reservoir and which increases the cost of a barrel of oil makes it less profitable to the producer. And, if this unnecesary cost is added to the price, it becomes less attractive in the world market and in relation to competing fuels.

At first glance, it is difficult to understand how oil companies can train engineers and production men, gather large amounts of material, ship them halfway around the world, pay 50 percent of the profits as royalty on every barrel of oil produced, then haul it back halfway around the world and lay it down at U. S. ports substantially cheaper than domestic oil. At second glance, the answer is simple—*more barrels of oil per well and lower unit costs.*

If this is the answer for foreign operations, does it not follow that the domestic industry should take another look at its own operations to see if all possible is being done to get the same benefits?

Nature might have been more lavish to the Middle East in the amount of oil deposited there, but she did not alter the basic laws of physics by which she allows it to be produced. Those laws are the same the world over, and are well understood by oil industry technicians.

Nearly every day there are reports of some well in some country being completed at a rate of six or seven thousand barrels a day. However, just one look at the East Texas proration schedule will show wells potentialed at more than 24,000 barrels per day. The Yates field has wells which will compete admirably with any on the face of the earth.

Capacity vs. waste. *It is not the individual well capacity that counts; the rate at which the reservoir can produce without waste is the critical consideration.*

When an operator drills more wells than are necesary to efficiently drain a reservoir, he has added unnecessarily to the cost of development and production. If it is determined that a reservoir is not being efficiently drained by wells on wide spacing, and there are accepted ways of determining this, more wells can always be drilled. But, has anyone ever tried to economically undrill a well?

The end result of drilling on wide spacing patterns does not necessarily mean fewer wells will be drilled. If a more realistic return on investment

State governments can help the oil industry correct its economic ills by taking action that will result in:

Equitable Unitization Laws

Needed in all states that do not have them. Texas in particular needs one because of its prominent place in domestic production.

Wider Well Spacing

A change is needed in the concept that 20 or 40 acres for an oil well and 80 to 160 acres for gas wells constitutes wide spacing. Operators, royalty owners and regulatory agencies should recognize that the efficient and economic exploitation of a field will benefit everyone concerned.

More Realistic Proration Formulas

Proved reserves should be a dominant factor in determining the equations. (The formula now under study by the State of Louisiana assigns 50 percent weight to reserves.) Proration formulas that give disproportionate weight to the well factor do not contribute to the industry's efforts to maintain an orderly spacing program.

Rules to Encourage Offshore Production

Because of the unique conditions offshore (cost of development, single royalty ownership, transportation problems, etc.), and because of its importance to national security, special rules should be established. The rules need not cause a reduction in onshore allowables, but should permit offshore's proportionate share of the total production to be produced from as few wells as can efficiently drain a field. The Federal Power Commission should take cognizance of this in considering its price fixing for gas.

Regulations That Encourage Efficiency

Regulations should not deny the operator the right to use to the fullest new developments which increase the efficiency of completion, measuring and operating techniques and equipment, i.e., multiple completions, metering oil and gas, automation of lease facilities. The rules should encourage rather than deny their application once they have been proved sound and equitable.

could be realized through higher per-well production rates, this profit would unquestionably flow into additional exploratory effort, resulting in new discoveries which would require development.

Exploration effort is an expense, and, from some place within the earning structure of an individual operator or of a company enough profit must be generated to support this activity. Unnecessarily increasing the cost of developing established reserves does not accomplish this. If the oil industry cannot make money on its proved reserves, it is difficult to conceive where the money is coming from to find additional reserves.

Needed: higher single well production. Onshore, private ownership of land poses a problem of protecting property rights which, in far too many cases, has been the primary cause for drilling wells which were not needed to efficiently produce a reservoir. Substantial progress has been made in many states to correct this economic waste through compulsory unitization laws (Louisiana, Oklahoma, Alabama, Arkansas, Mississippi and New Mexico). Other states have means to accomplish essentially the same results through their proration formulas.

Louisiana, through its Department of Conservation, at the present time has a study in progress to arrive at new formulas for prorating oil which will minimize the need to drill unnecessary wells. This is one of the most important forward steps that any regulatory body has taken in many years.

The development and administration of fair, equitable and realistic formulas may well spell the difference between a strong, healthy domestic industry, and an industry striving for survival with little opportunity for expansion.

Offshore proration—a major problem. To date, the success ratio for offshore discoveries of oil and gas has been excellent. Large reserves of both have been found, and many, many more remain to be found. Yet, it is apparent that there is growing concern about developing these vast reserves.

What is wrong with a system which makes it questionable for a company accustomed to taking risks in exploring for oil to hestitate to proceed to develop it after it has been found?

There is only one answer: The production allowed each well is not sufficiently large to yield an attractive return on the large investment necessary to drill the well itself, let alone provide enough profit to build pipe lines to get ashore, or carry on additional exploratory work.

The present method of increasing production is to drill more wells. This completely disregards the ability of the well to produce, or the reserves behind the well to sustain its production. The same total amount of oil being produced offshore today could be produced efficiently from about half as many wells. Wide spacing, higher well allowables and an opportunity for the industry to produce oil as efficiently and economically as it knows how seem particularly appropriate in an area where there is no diversity in royalty ownership.

Why regulate efficiency? Regulations should not deny the operator the right to use to the fullest new developments in completion, measuring and operating techniques and equipment, i.e., multiple completions, metering oil and gas, automation of lease facilities or any other method or device that adds to the economy of producing. The rules should encourage, rather than deny, their application once they have been proved sound and equitable.

ACKNOWLEDGMENT

The above article was written from a speech presented by E. B. Miller, Jr., vice president and general manager of Tidewater Oil Company's Southern division, before the May 26 dinner meeting of the Dallas-Fort Worth Chapter of the American Association of Oilwell Drilling Contractors.

Oil industry purchases at record high

$1.1 billion worth of equipment, materials and services were purchased during 1957—an increase of 3.32 percent over 1955.

THE U. S. OIL industry purchased more equipment, materials and services in 1957 than ever before, despite a downturn in activity during the latter months.

Total purchases: $1,132,995,694—an increase of 3.32 percent over 1955, the last recorded year. Of this total, about 18 percent, or $203.9 million was for services, and the remaining $929.1 million was spent for equipment and materials. This compares with the 1955 total of $199.7 million for services and $896.9 million for goods.

These figures were presented June 30 at the 23rd annual meeting of the Petroleum Equipment Suppliers Association, Quebec, Canada. The report was based on a biennial study conducted for the Business and Defense Services Administration of the Department of Commerce.

At the time of presentation, the study was 90.5 percent complete, with 412 out of 455 companies reporting. Estimates are that final returns will increase the total about $20 million.

Other highlights of the report included breakdowns of dollar volume in the four largest service and supply areas, and the extent of materials usage by years in the major areas.

Houston volume increases. Four major areas (Houston, Los Angeles, Tulsa, Dallas-Fort Worth) accounted for 66.7 percent of the industry's total purchases in 1957, compared with 68 percent in 1955 and 61.9 percent in 1954.

Houston Area reported the largest volume of goods and services sold, and the largest increase in percent of total volume. Houston's share of total oil industry purchases in 1957 was up 2.3 percent over 1955 and 3.6 percent over 1954.

Total dollar volume and percent of total by years:

1957: $427,560,515—37.7% of total.
1955: $387,837,887—35.4% of total.
1954: $316,499,292—34.1% of total.

Los Angeles Area also increased its share of the total dollar volume last year—1 percent over 1955 and 3.5 percent over 1954.

Total dollar volume and percent of total by years:

1957: $168,021,474—14.8% of total.
1955: $151,762,177—13.8% of total.
1954: $104,554,419—11.3% of total.

Tulsa Area reported a decrease in percent of total dollar volume. The area's 1957 share of the total was 2.8 percent under 1955 and 2.1 percent under 1954.

Total dollar volume and percent of total by years:

1957: $94,261,905—8.4% of total.
1955: $122,541,941—11.2% of total.
1954: $97,322,432—10.5% of total.

Dallas-Fort Worth Area also reported a decline in its share of the total volume—1.8 percent under 1955 and 0.2 percent under 1954.

Total dollar volume and percent of total by years:

1957: $65,261,905—5.8% of total.
1955: $83,420,456—7.6% of total.
1954: $56,687,765—6.0% of total.

Sharp rise in dollar volume of steel. The U. S. oil industry purchased 3,530,928 tons of carbon and alloy steel last year (includes oil field machinery, equipment and oil country goods). This does not include exports or such unreported items and imported pipe, inventory withdrawals and second hand pipe.

The estimated dollar value of shipments to the industry of carbon and alloy steel for oil country goods (pipe and tubing) was $589,872,403, up 29.6 percent over 1955. Total shipments (2,822,641 tons) were up 15.8 percent.

The 1957 requirements for carbon and alloy steel (OFME and oil country goods) are reported to be 9.94 percent above 1955. However, steel consumption by the oil industry for production and services is less than the 1955 total. This is also true regarding the majority of controlled materials consumed during 1957.

Changing Trends in Oil Industry Materials Usage Since 1954

MATERIAL	1957	Percent Change	1955	Percent Change	1954
Carbon Steel	478,434 Tons	— 9.1	526,190 Tons	+ 10.0	478,423 Tons
Alloy Steel	229,853 Tons	— 7.4	248,294 Tons	+ 21.3	204,771 Tons
Nickel Bearing Stainless	5,066 (M) lbs.	— 47.4	9,632 (M) lbs.	+199.6	3,215 (M) lbs.
Non-Nickel Bearing Stainless	6,134 (M) lbs.	+173.1	2,246 (M) lbs.	+ 4.1	2,158 (M) lbs.
Nickel Alloys	965 (M) lbs.	.....	.....	.....	.....
Copper and Copper Base Alloy (Brass Mill)	3,969 (M) lbs.	— 20.1	4,965 (M) lbs.	+ 23.1	4,034 (M) lbs.
Copper Wire Mill Products	1,953 (M) lbs.	+ 9.5	1,783 (M) lbs.	+ 45.4	1,226 (M) lbs.
Copper and Copper Base Alloy (Foundry Products)	5,480 (M) lbs.	+ 6.5	5,147 (M) lbs.	+ 33.1	3,866 (M) lbs.
Copper and Copper Base Alloy (Powder Products)	6 (M) lbs.	— 81.8	33 (M) lbs.	— 65.3	95 (M) lbs.
Aluminum	3,997 (M) lbs.	— 30.6	5,757 (M) lbs.	+ 29.0	4,462 (M) lbs.

—The End

CHANGING PANORAMA . . .

U.S. moves to increase helium supply

Bureau of Mines has requested industry proposals to use as guides in preparing tighter helium conservation measures.

By Harrison T. Brundage
WORLD OIL Staff

THE NATURAL GAS industry is keeping a close watch on federal government efforts to increase the U. S. helium supply. Reason: Extra profits may be in the offing.

The plan is to encourage closer industry-government cooperation in tightening present helium conservation policies. The need for such action is based on three factors vital to the nation's defense:

1. Industrial demand is spiraling.
2. Increased government and industrial use has spurred a U. S. Bureau of Mines proposal to build upwards of 12 new helium plants. Estimated cost: $224 million.
3. Present supply is not keeping pace with demand, leaving the outlook doubtful for increased helium use.

Current U.S. helium production is about a million cubic feet daily. However, more than ten times that amount now is being transported with natural gas and vented to the atmosphere when the gas is burned in homes and factories.

New uses, not only for national defense but also for helium-shielded arc welding and special medical techniques, are boosting helium needs. Essential demand currently is being met, but, considering non-essential markets for helium now being denied by the Bureau of Mines, there is a shortage of helium.

What is being done. On May 1, Secretary of the Interior Fred Seaton announced a new conservation policy for helium, contingent on new legislation and expanded appropriations to be introduced in Congress.

Following Seaton's announcement, the Helium Liaison Section of the Bureau of Mines is drafting legislation intended to give it more authority to deal with private firms to effect more widespread separation of helium from natural gas streams now being put into pipe lines. The Bureau of Mines is seeking proposals from interested industry parties to serve as guideposts in preparing the legislation.

By law, only the federal government can market helium. Since government-owned facilities heretofore have been able to produce enough helium to meet demand, it generally has not been considered practicable to strip it from low helium content natural gas.

Under the new program that philosphy will be changed, thus conserving up to 32 billion cubic feet of helium. This estimate is based on utilization of natural gas with as little as 0.4 percent helium content by volume. However, it may be that as low a content as 0.2 percent helium in natural gas may be separated and used, under proper conditions.

New legislation may enable the Bureau of Mines to arrange for helium extraction jointly with companies processing natural gas for butane, propane and petrochemicals. This is one reason why the Bureau of Mines is asking for a variety of proposals to be considered in drawing up new legislation.

Where helium is found. Helium occurs in minor volumes in a few areas where structural and stratigraphic traps overlie buried granite ridges, such as the Amarillo Mountains and the Nemaha Ridge. It is thought to be derived entirely from natural radioactive disintegration.

Since igneous uranium minerals are genetically associated with granite magmas, it is natural that helium should occur in appreciable quantities only in ancient sediment overlying granite bodies.

Bureau of Mines requests and obtains samples of gas from all fields in the U.S., hence carries on a continuous, comprehensive exploration for helium. The only new sources of helium uncovered in recent years are in Utah, and they are thought to be minor in extent.

Location of helium plants. The Bureau of Mines is operating three plants, two of which are in the Texas Panhandle-Hugoton area. The Amarillo, Texas, plant, first operated in 1929, has an expanded capacity of 6 MMcf of helium per month. Another at Excell, Texas, has an expanded capacity of 18 MMcf monthly.

The only helium plant outside the Panhandle-Hugoton area, located at Navajo (Shiprock), N. M., has a capacity of 4 MMcf monthly. However, in recent years several wells in the Rattlesnake field have gone to water, casting doubt on the ability of the producing area to supply enough helium to keep the Shiprock plant operating.

The Bureau of Mines currently is selling helium to other government agencies at $15.50 per Mcf, and at $19.00 Mcf to non-government buyers. Seventy percent of the helium now produced is used in defense (including missisles), and another 20 percent is used on government contracts, leaving only 10 percent for civilian use. Currently, the Bureau of Mines is turning down new buyers because of the uncertainty of future supply and essential current requirements.

Plans for new pipe lines. Helium is transported in specially designed pressurized tank cars and in pressure vessels. However, the increasing demand for helium has made it necessary to consider the possibility of transporting it in liquid form, despite the extremely low temperatures required to liquify it.

In addition to the proposed plants, new facilities to be built probably will include some pipe lines to storage facilities at Cliffside field. However, the pipe lines will probaly not be larger than 4-inch diameter. And, since about 99 percent of the country's recoverable helium is located within 250 miles of Amarillo, any new lines will be relatively short.

Outlook for second half of year encouraging

THE OUTLOOK for the petroleum industry has continued to grow brighter. Demand for gasoline and other products has been improving. The demand is expected to continue to be favorable in the latter half of the year.

Earlier surpluses of crude oil and refined products have been largely eliminated by holding new supplies somewhat under current demand. Imports, crude production, and refinery output of products have been held down to levels resulting in withdrawals of some of the excess oils from storage.

As a result of the balance between supply and demand and elimination of surplus stocks, the markets for crude oil and refined products have been improving steadily and are now relatively firm.

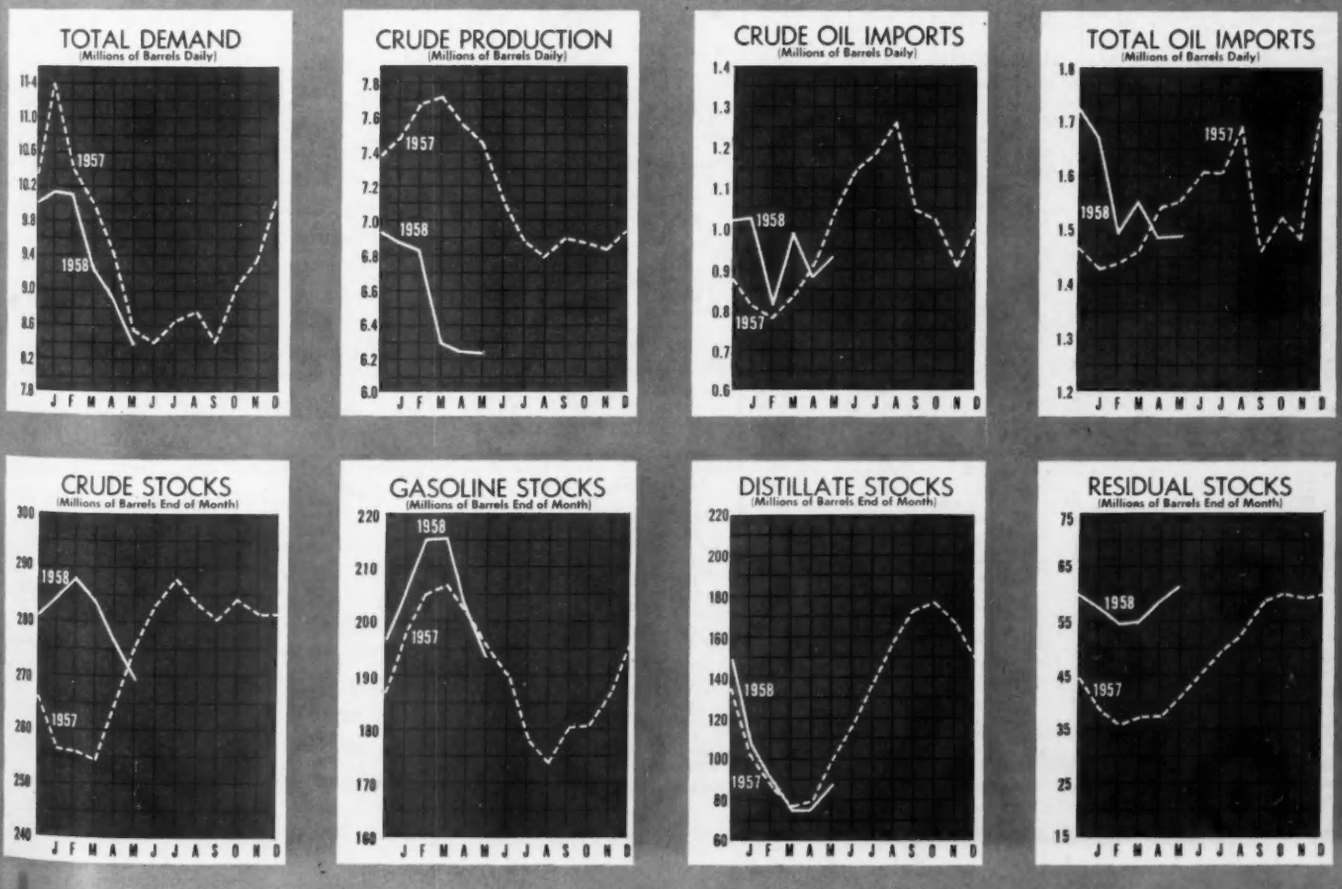
Prices of refined products are still depressed, following the decline that started around the middle of last year. But some recovery got under way in early June, when wholesale prices of gasoline were advanced as much as one half cent a gallon by numerous companies in several Mid-Continent states.

About the same time, however, there were further downward adjustments in posted prices of some special grades of crude oil. A further cut of 25 cents a barrel in Pennsylvania grade crude was posted. Used for making lubricants, that crude has been in lower demand because of the recession. In California, prices of heavier crudes were reduced, because of surplus stocks and overproduction, with supplies of heavy fuel oils exceeding demand.

Concrete evidence of a definite change for the better in the petroleum industry situation was given at mid-June, when Texas crude oil production allowables for July were increased. The Texas Railroad Commission's new proration order will permit production during nine days in July. April, May, and June were on record low allowables of eight producing days per month. The new allowable, permitting 2,604,798 barrels daily average production during July, represents an increase of 121,745 barrels daily, or 4.9 percent above the mid-June allowable.

The commission raised the Texas allowables on the basis of conclusive evidence of increased market demand. Major purchasers cited lowered crude

Petroleum Trends...



U. S. MONTHLY OIL TRENDS

(Thousands of Barrels Daily)

	MAY			April	JANUARY-MAY		
	1958	1957	%Diff.	1958	1958	1957	% Diff.
U.S. Crude Oil Production	6,245	7,442	—16.1	6,240	6,482	7,570	—14.4
U.S. Nat. Gas Liquids Prod.	780	814	— 4.2	800	800	827	— 3.3
U.S. Total Imports	1,484	1,558	— 4.8	1,486	1,624	1,485	+ 9.4
East Coast Crude Imports	753	760	— 0.9	754	783	652	+20.1
Total Crude Imports	936	1,042	—10.2	891	941	875	+ 7.5
Total Refined Products	467	516	— 9.5	595	667	609	+ 9.5
Total New Supply	8,509	9,814	—13.3	8,526	8,906	9,882	— 9.9
Stock Changes All Oils (Daily)	+129	+1,271	.....	—334	—529	—71	.....
Total Demand All U.S. Oils	8,380	8,543	— 1.9	8,860	9,435	9,953	— 5.2
Gasoline Demand	4,075	4,104	— 0.7	4,043	3,742	3,823	— 2.1
Distillate Fuel Demand	1,100	1,188	— 7.4	1,583	2,090	2,178	— 4.1
Residual Fuel Demand	1,150	1,462	—21.4	1,384	1,581	1,790	—11.7
Domestic Demand, All Oils	8,155	8,011	+ 1.8	8,630	9,186	9,123	+ 0.7
Export Demand, All Oils	225	536	—58.0	230	249	830	—70.0
Crude Runs U.S. Refineries	7,397	7,992	— 7.5	7,160	7,422	8,029	— 7.6
Domestic Crude Runs	6,491	6,998	— 7.3	6,300	6,518	7,170	— 9.1
Foreign Crude Runs	906	994	— 8.9	860	910	859	+ 5.9

	TOTAL U.S. STOCKS Millions of Barrels End of Month				STOCKS EAST OF CALIFORNIA Millions of Barrels End of Month			
	May			April	May			April
	1958	1957	% Diff.	1958	1958	1957	% Diff.	1958
Crude Oil	268.8	276.0	— 2.6	276.0	212.6	244.6	—13.1	237.1
Gasoline	193.3	195.1	— 0.9	203.2	166.3	166.9	— 0.4	175.0
Distillate Fuel Oil	89.3	98.1	— 9.0	76.0	81.8	87.1	— 6.1	64.4
Residual Fuel Oil	61.8	41.0	+50.7	58.0	30.7	27.5	+11.6	26.8
Kerosine	21.7	28.9	—24.9	18.6	21.3	25.2	—15.5	18.3

Source: Except for latest two months, all data from U.S. Bureau of Mines. Data for last two months from American Petroleum Institute weekly reports and U.S. Bureau of Mines weekly crude stock report; except U.S. Natural Gas Liquids Production and Demand figures which are estimated by World Oil.

U. S. Crude Production by States

(THOUSANDS OF BARRELS)

	DAILY AVERAGE PRODUCTION				TOTAL PRODUCTION		
	May			April	January-May		
STATE or DISTRICT	1958	1957	% Dif.	1958	1958	1957	% Dif.
Alabama	14.9	15.7	— 5.1	17.0	2,411	2,032	+ 18.7
Arkansas	79.6	83.6	— 4.8	82.8	12,304	12,909	— 4.7
California	855.2	927.2	— 7.8	867.3	132,773	140,865	— 5.8
Colorado	136.3	153.0	— 10.9	138.7	20,829	23,616	— 88.2
Florida	1.1	1.4	— 21.4	1.3	185	192	— 3.7
Illinois	219.2	221.1	— 0.9	222.2	33,464	32,998	+ 1.4
Indiana	29.5	36.9	— 20.1	30.8	4,677	5,511	— 15.1
Kansas	321.4	342.1	— 6.1	320.7	47,718	50,047	— 4.7
Kentucky	42.0	46.2	— 9.1	43.0	6,392	7,014	— 8.9
Louisiana	814.3	940.3	— 13.4	824.6	124,948	148,965	— 16.1
North Louisiana	115.9	131.4	— 11.8	115.7	17,247	20,673	— 16.6
South Louisiana	698.4	808.9	— 13.7	708.9	107,701	128,292	— 16.1
Michigan	25.6	28.6	— 10.5	24.1	3,793	4,302	— 11.8
Mississippi	102.2	114.9	— 11.1	103.3	15,506	17,256	— 10.2
Missouri-South Dakota-Tennessee	0.3	0.3	.....	0.3	51	39	+ 30.8
Montana	73.9	73.4	+ 0.7	73.8	11,262	10,808	+ 4.2
Nebraska	52.3	48.1	+ 8.7	50.3	7,926	7,519	+ 5.4
Nevada	0.1	.....	.....	0.1	15	12	+ 25.0
New Mexico	274.2	258.1	+ 6.2	257.1	39,452	39,838	— 1.0
Southeast New Mexico	246.7	252.5	— 2.3	251.6	37,654	38,927	— 3.3
Northwest New Mexico	27.5	5.6	+391.1	5.5	1,798	911	+ 97.4
New York	6.8	7.8	— 12.8	6.7	983	1,130	— 13.0
North Dakota	35.4	39.9	— 11.3	36.6	5,790	5,959	— 2.8
Ohio	17.4	14.3	+ 21.7	18.2	2,576	2,074	+ 24.2
Oklahoma	545.8	600.8	— 9.2	542.2	82,975	94,475	— 12.2
Pennsylvania	19.2	24.1	— 20.3	18.8	2,844	3,497	— 18.7
Texas	2,203.1	3,156.4	— 30.2	2,222.8	368,969	485,118	— 24.0
Dist. 1: South Central	45.5	57.3	— 20.6	45.3	6,949	8,571	— 18.9
Dist. 2: Middle Gulf	95.9	156.3	— 38.7	97.9	16,701	24,375	— 31.5
Dist. 3: Upper Gulf	346.7	466.4	— 25.7	348.1	56,276	70,785	— 20.5
Dist. 4: Lower Gulf	160.6	237.3	— 32.3	164.7	27,186	37,083	26.7
Dist. 5: East Central	25.6	40.5	— 36.8	27.4	4,478	6,324	— 29.2
Dist. 6: Northeast	214.4	347.4	— 38.3	220.2	37,391	53,979	— 30.7
Dist. 7-B: North Central	122.4	167.1	— 26.8	128.9	20,408	25,227	— 19.1
Dist. 7-C: West Central	114.1	172.9	— 34.0	113.6	19,370	26,364	— 26.5
Dist. 8: West	779.4	1,186.0	— 34.3	778.4	132,174	179,348	— 26.3
Dist. 9: North	191.8	218.4	— 12.2	190.6	29,374	32,392	— 9.3
Dist. 10: Panhandle	106.8	110.2	— 3.1	107.7	16,138	15,882	+ 1.6
Utah	69.5	7.8	+791.0	28.1	4,399	1,539	+185.8
Virginia	.....	.....	.....	.....	2	2	.....
Washington	.....	.....	.....	.....	3	.....	.....
West Virginia	6.2	6.2	.....	6.5	898	901	— 0.3
Wyoming	300.0	293.7	+ 2.1	302.5	45,579	44,502	+ 2.4

Source: Bureau of Mines and API. Texas districts from API and do not necessarily agree with state totals.

stocks and indicated varying needs for 9 to 13 days' production in July. Five companies asked for nine days of production, four recommended 10 days, two wanted 11, one requested 12, and one 13. The largest buyer of Texas crude reported stocks below minimum working levels and advised 11 producing days. A company requesting 12 days' production estimated crude stocks outside California as 9 million barrels less than desirable. Producers indicated that purchaser proration in Texas had been largely eliminated.

Total petroleum demand in the third quarter of this year will be about the same as in the like period last year. This is the forecast of the Independent Petroleum Association of America. Domestic demand will be up 1.3 percent, it predicted, but that gain will be offset by a decrease of 100,000 barrels daily in exports.

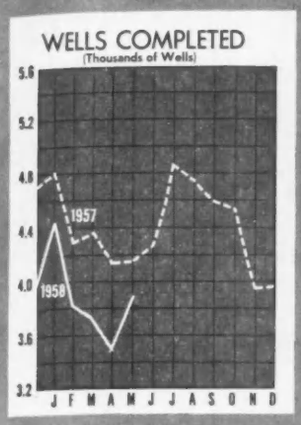
In the first five months of 1958, said IPAA, total demand was off 5.9 percent from 1957, with domestic consumption about unchanged at 8,250,000 barrels daily but exports down 66 percent to 270,000 daily from the Suez crisis period.

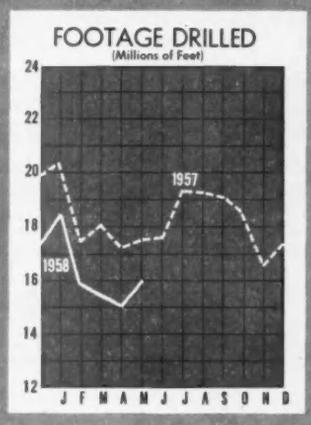
The market for domestic crude will increase in the third quarter to about 7 million barrels daily average from about 6,325,000 daily in June, IPAA estimated. The gain will result from current low crude stocks and improving demand.

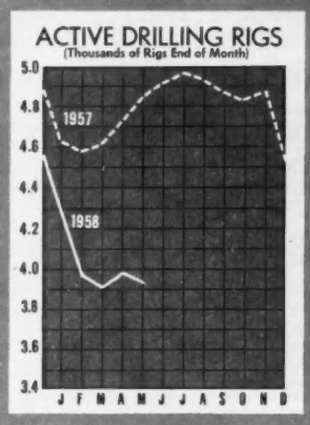
John G. Winger, economist, Chase Manhattan Bank, in late June predicted that the second half of 1958 would bring an increase of possibly 1 million barrels daily in needed new petroleum supply, over June rates. Factors boosting demand, he said, will include the federal highway building program, increasing agricultural use, and a business recovery beginning in the fourth quarter. Increased crude supplies should come mainly from U. S. fields, the economist said, and especially from Texas, where curtailment has been drastic. He added that there was probably room for 78 producing days in Texas in the second half, an average of 13 per month.

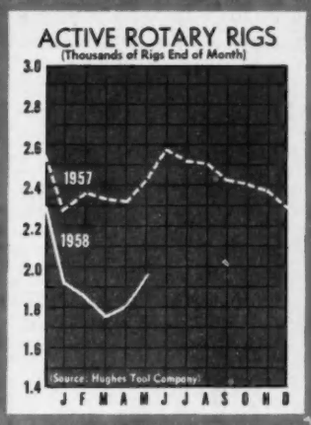
There is no more talk, said Winger, of a general crude price cut. In the first 12 months following the present recession, domestic demand for oil may increase by 8 percent, he stated, and by 1967 it should be 14 million barrels a day.

Drilling Activities...









May shows year's first upturn with 3,910 new wells

THE YEAR'S first upturn in U. S. drilling activity occurred in May when 3,910 new wells were completed. This total did not match January's, but it represented the first upward move since the opening month. In fact, May's wells topped the previous four months' average by 6.6 percent.

Whether this upward trend will be sustained in the following months remains to be seen. However, June started with the disadvantage of having slightly fewer active drilling rigs in the field than were at work at the start of May. The better-than-average showing made in May was the result of almost 4,000 rigs being active at the month's outset. That was the greatest rig concentration in the U. S. since January. June's work got started with 58 fewer rigs nationally, and the results may be slightly fewer completed wells.

By the end of May, this year's wells trailed last year's by 11.2 percent. A month earlier, the differential had been 12.4 percent in favor of 1957. The current totals are 19,364 new wells in this year's first five months against 21,792 completed in the comparable period of last year.

Total footage drilled in May continued climbing to 16.1 million feet of hole as compared with 15.1 million feet for April. There has been an accumulated total of 80,786,827 feet of hole drilled during the first five months of 1958, a decrease of 11 percent compared to the same period last year, but with an increase of average depth per well.

Increased activity for the month was represented mostly in gains in various states from the middle west and southwestern sections of the country. The Louisiana-Texas area claimed 6.9 percent increase over April but still showed 13.1 percent fewer wells than those completed in the same month last year. Oklahoma had the largest percentage gain with 589 wells completed in the month as compared to 519 wells in April and 363 completions in May 1957.

The Four Corners area dropped in well completions during May but the increase in the number of rigs active at the end of the month indicates recovery during the next thirty day period.

Wildcat wells increased 13.7 percent over the number of exploratory wells drilled during April, but still the year's record lags 16.4 percent behind last year. Through May, 1957, there had been 505 new field discoveries against 465 for the same period this year. As was true last year, Texas was credited with more than 40 percent of the new discoveries.

Summary of U. S. Wildcat Drilling

ITEM	May 1958	April 1958	FIVE MONTHS January-May 1958	1957	% Diff.
New Fields Discoveries:					
Oil	63	67	310	348	— 10.9
Distillate	11	9	45	59	— 23.7
Gas	22	22	110	98	+ 12.2
Total Discoveries	96	98	465	505	— 7.9
Dry Wildcats	693	596	3,370	4,082	— 17.5
Total Wildcats	789	694	3,835	4,587	— 16.4
Percent Productive	12.2	14.1	12.1	11.0	.....
Percent Dry	87.8	85.9	87.9	89.0	.....

Summary of U. S. Drilling Activity

ITEM	May 1958	April 1958	FIVE MONTHS January-May 1958	1957	% Diff.
New Wells Completed:					
Oil	1,937	1,829	9,738	11,721	— 16.9
Distillate	71	62	344	278	+ 23.7
Gas	308	307	1,608	1,448	+ 11.0
Service	133	122	672	408	+ 64.7
Dry	1,461	1,233	7,002	7,937	— 11.8
Total Wells	3,910	3,553	19,364	21,792	— 11.2
Footage Drilled (Mln. of Feet)	16.0	15.0	80.8	90.8	— 11.0

Details on next page

U. S. Drilling Activity in May and First Five Months, 1958-1957

STATE or DISTRICT	TOTAL NEW WELLS COMPLETED AND FOOTAGE DRILLED: DETAILS FOR MAY, 1958 — Oil	Dist.	Gas	Dry	Service Wells	TOTAL NEW WELLS — May 1958	April 1958	May 1957	Total Footage May 1958	DETAILS FOR JANUARY-MAY: NEW WELLS — 1958	1957	Percent Diff.	FOOTAGE — 1958	1957
Alabama	4	....	....	2	....	6	8	10	53,112	31	51	— 39.2	273,347	460,626
Arkansas	25	....	5	32	....	62	48	71	244,283	263	392	— 32.9	906,150	1,126,816
California	77	....	4	37	....	118	113	195	497,527	640	899	— 28.8	2,982,009	3,868,041
Colorado	19	....	4	37	....	60	58	55	320,205	300	329	— 8.8	1,586,911	1,712,947
Florida	....	....	....	....	....	....	....	....	.....	2	6	— 66.7	18,942	40,312
Georgia	....	....	....	....	....	....	....	....	.....	....	3	—100.0	.....	18,955
Illinois	69	....	5	116	1	191	137	209	427,948	819	958	— 14.5	1,828,353	2,129,504
Indiana	19	....	1	38	....	58	48	81	90,232	252	273	— 7.7	408,698	423,199
Kansas	143	....	20	153	8	324	243	318	1,089,271	1,345	1,667	— 19.3	4,616,651	5,936,672
Kentucky	45	1	10	52	1	109	102	144	145,797	509	579	— 12.1	731,366	888,274
Louisiana	118	20	28	103	....	269	261	309	2,333,142	1,362	1,455	— 6.4	11,389,206	12,260,795
North Louisiana	38	1	15	28	....	82	85	91	282,521	448	499	— 10.2	1,724,184	1,856,150
South Louisiana	80	19	13	75	....	187	176	218	2,050,621	914	956	— 4.4	9,665,022	10,404,645
*Gulf of Mexico	26	4	2	12	....	44	44	63	430,050	218	276	— 21.0	2,099,699	2,594,352
Michigan	14	....	4	27	....	45	28	38	132,308	151	162	— 6.8	435,949	462,940
Mississippi	7	1	....	11	....	19	30	35	170,385	149	158	— 5.7	1,298,151	1,116,411
Missouri	....	....	....	....	....	....	6	1	.....	6	1	+500.0	3,255	370
Montana	14	....	....	12	....	26	22	28	114,492	131	132	— 0.8	737,262	737,100
Nebraska	16	....	....	44	....	60	28	85	357,912	231	339	— 31.9	1,378,617	2,007,106
Nevada	....	....	....	....	....	....	....	....	.....	....	3	—100.0	.....	5,718
New Mexico	73	....	25	26	1	125	123	182	599,918	793	926	— 14.4	3,797,557	4,164,869
Southeast	57	....	3	15	1	76	69	107	379,944	424	605	— 29.9	2,143,902	2,858,335
Northwest	16	....	22	11	....	49	54	75	219,974	369	321	+ 15.0	1,653,655	1,306,534
New York	21	....	1	2	24	48	48	39	73,800	240	192	+ 25.0	369,000	327,700
North Dakota	19	....	....	16	....	35	38	22	229,567	168	114	+ 47.4	1,151,297	783,652
Ohio	41	....	19	14	....	74	82	72	189,497	391	373	+ 4.8	1,014,019	935,179
Oklahoma	318	8	26	199	38	589	519	363	1,862,021	2,906	2,448	+ 18.7	9,307,598	8,984,207
Pennsylvania	35	....	22	7	34	98	104	75	238,328	500	372	+ 34.4	1,209,005	1,068,214
South Dakota	....	....	....	....	....	....	....	5	.....	3	23	— 87.0	16,991	83,721
Texas	805	41	105	499	26	1,476	1,372	1,698	6,302,956	7,412	9,372	— 20.9	32,156,154	39,117,104
Dist.1: South Central	37	1	1	41	....	80	81	95	192,404	425	602	— 29.4	1,070,819	1,521,341
Dist. 2: Middle Gulf	22	12	10	31	1	76	89	75	445,390	326	301	+ 8.3	1,962,024	1,899,444
Dist. 3: Upper Gulf	55	12	5	50	....	122	113	137	663,983	566	740	— 23.5	3,525,532	5,056,628
*Gulf of Mexico	....	....	1	1	....	2	1	....	13,502	5	5	.....	37,287	37,935
Dist. 4: Lower Gulf-S.W.	33	13	10	67	....	123	102	131	643,722	521	603	— 13.6	2,683,984	3,204,973
*Gulf of Mexico	....	....	....	....	....	....	2	1	.....	4	8	— 50.0	49,059	77,907
Dist. 5: East Central	3	....	1	9	....	13	4	7	53,016	65	67	— 3.0	252,418	311,655
Dist. 6: Northeast	33	1	7	30	....	71	61	81	355,080	362	456	— 20.6	1,910,379	2,495,072
Dist. 7-B: North Central	84	1	2	87	3	177	159	220	560,394	884	1,160	— 23.8	2,898,811	3,934,625
Dist. 7-C: West Central	34	....	1	17	....	52	47	104	261,267	336	526	— 36.1	1,753,977	2,303,116
Dist. 8: West	312	1	5	66	4	388	355	423	1,770,331	1,824	2,142	— 14.9	8,926,170	10,461,037
Dist. 9: North	158	....	30	77	18	278	261	323	867,135	1,573	2,195	— 28.3	4,758,606	5,632,317
Dist. 10 Panhandle	39	....	33	24	....	96	100	102	490,234	530	580	— 8.6	2,413,434	2,296,896
Utah	20	....	....	7	....	27	41	18	154,740	198	67	+195.5	1,110,000	398,479
Washington	....	....	....	....	....	....	1	....	.....	4	1	+300.0	20,794	5,980
West Virginia	7	....	27	10	....	44	48	44	161,350	275	227	+ 21.1	738,293	622,272
Wyoming	28	....	1	15	....	44	42	53	233,936	276	269	+ 2.6	1,275,000	1,153,212
Others	....	....	1	2	....	3	3	....	12,984	7	1	+600.0	26,252	3,947
Total United States	1,937	71	308	1,461	133	3,910	3,553	4,150	16,035,711	19,364	21,792	— 11.2	80,786,827	90,843,322
Total Western Canada	69	....	27	64	....	160	124	47	851,115	893	1,097	— 18.6	5,031,516	5,204,903

STATE or DISTRICT	WILDCAT DRILLING IN MAY AND FIRST FIVE MONTHS, 1958-1957: DETAILS FOR MAY, 1958 — Oil	Dist.	Gas	Dry	Total Wildcats	DETAILS FOR JANUARY-MAY — Oil	Dist.	Gas	Dry	TOTAL WILDCATS — 1958	1957	DRILLING RIGS IN OPERATION (Rigging up, Drilling, Temp. Shut-Down) — May 31, 1958	April 30, 1958	May 31, 1957
Alabama	....	....	....	....	....	....	....	....	11	11	17	10	12	20
Arkansas	....	....	....	....	....	5	....	....	55	65	52	7	49	85
California	....	....	....	....	....	3	....	1	98	102	150	136	136	196
Colorado	....	....	....	....	....	15	....	5	128	148	198	54	45	48
Florida	....	....	....	....	....	....	....	....	2	2	6	1	1	1
Georgia	....	....	....	....	....	....	....	....	....	....	3	....	....	....
Illinois	....	....	....	....	....	....	....	....	214	215	280	268	261	239
Indiana	....	....	....	47	47	1	....	....	69	72	76	95	78	101
Kansas	....	....	....	23	23	2	....	1	295	355	390	379	452	545
Kentucky	18	....	4	79	101	49	....	11	25	28	45	109	88	132
Louisiana	1	....	....	2	3	2	....	1	183	213	232	349	344	435
North Louisiana	....	....	....	6	6	6	....	....	42	48	59	93	81	77
South Louisiana	1	2	1	33	37	12	9	3	141	165	173	256	263	358
*Gulf of Mexico	1	....	....	5	6	3	1	....	15	19	34	50	45	96
Michigan	1	....	....	9	10	2	....	1	43	46	69	73	68	74
Mississippi	....	1	....	9	10	5	1	....	62	68	76	46	37	41
Missouri	....	....	....	....	....	....	....	....	1	1	2	1	....	1
Montana	....	....	....	11	11	3	1	3	48	55	40	35	38	52
Nebraska	2	....	....	31	33	12	....	....	98	110	177	40	35	46
Nevada	....	....	....	....	....	....	....	....	....	....	3	1	1	2
New Mexico	2	....	1	15	18	16	2	12	86	116	132	199	163	159
Southeast	2	....	....	8	10	11	2	4	49	66	86	75	73	90
Northwest	....	....	1	7	8	5	....	8	37	50	46	124	90	69
New York	....	....	....	....	....	....	....	....	....	....	....	50	45	59
North Dakota	....	....	....	10	12	14	....	....	34	48	49	36	36	26
Ohio	....	....	....	1	1	....	....	....	3	3	3	218	218	206
Oklahoma	5	3	3	53	64	27	5	15	250	297	275	447	526	571
Pennsylvania	....	....	2	1	3	....	....	8	3	11	21	134	105	166
South Dakota	....	....	....	....	....	....	....	....	3	3	22	1	....	3
Texas	25	5	6	280	316	131	27	37	1,538	1,733	2,144	935	1,018	1,349
Dist.1: South Central	2	....	....	37	39	7	1	1	147	156	169	31	35	45
Dist. 2: Middle Gulf	4	1	1	22	28	6	6	6	78	96	103	26	40	42
Dist. 3: Upper Gulf	....	1	1	28	30	3	3	4	130	140	197	75	95	142
*Gulf of Mexico	....	....	....	1	1	....	....	1	2	3	3	2	2	1
Dist. 4: Lower Gulf-S.W.	2	2	....	39	43	10	8	2	188	208	188	63	71	77
*Gulf of Mexico	....	....	....	....	....	....	....	....	1	1	....	2	1	4
Dist. 5: East Central	2	....	....	5	7	2	1	....	34	37	49	10	8	5
Dist. 6: Northeast	....	....	....	20	20	3	1	2	88	94	100	61	67	75
Dist. 7-B: North Central	3	1	1	37	42	28	3	5	278	314	412	70	90	111
Dist. 7-C: West Central	4	....	1	12	17	17	....	3	82	102	164	60	65	93
Dist. 8: West	5	....	....	40	45	28	....	4	190	222	213	292	309	398
Dist. 9: North	2	....	1	30	33	20	2	4	278	304	496	158	145	226
Dist. 10 Panhandle	1	....	1	10	12	7	2	6	45	60	53	89	93	135
Utah	....	....	....	4	4	....	....	....	36	36	36	34	47	51
Washington	....	....	....	....	....	....	....	....	3	3	1	....	1	....
West Virginia	....	....	....	1	1	....	....	4	3	7	7	135	132	170
Wyoming	....	....	1	7	8	5	....	2	73	80	80	79	53	87
Others	....	....	1	2	3	....	....	1	6	7	1	7	7	3
Total United States	63	11	22	693	789	310	45	110	3,370	3,835	4,587	3,938	3,996	4,868
Total Western Canada	....	....	....	....	....	....	....	....	.....	.....	.....	215	165	241

* Gulf of Mexico wells are included in their respective district totals.

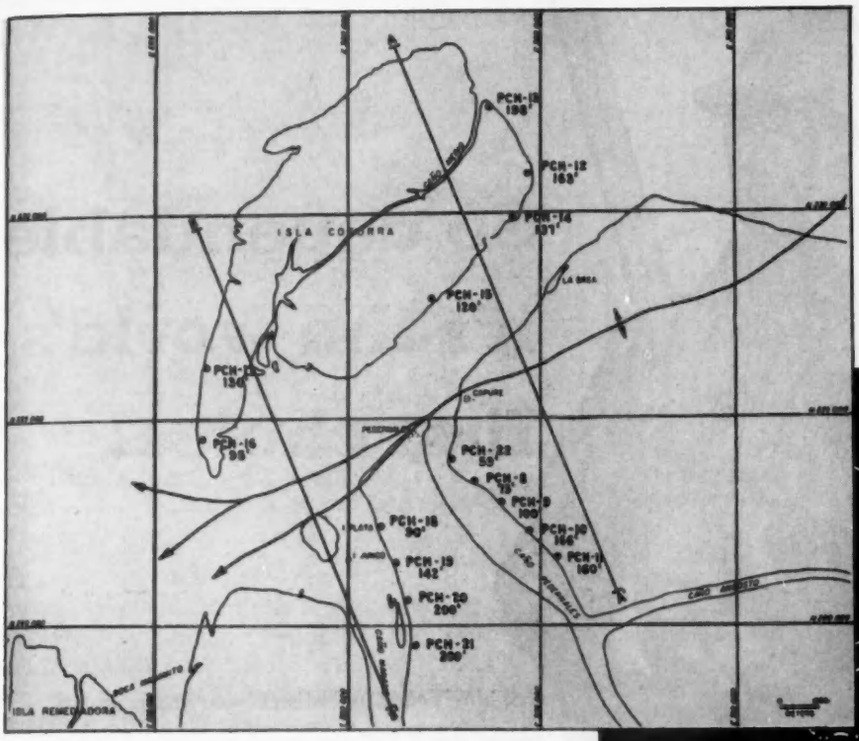


FIGURE 2—(Above) Detail map of this region showing the location of holes drilled on the flanks of the structure. Depths to pre-Paria unconformity are indicated at each hole location.

← Axis of Pedernales structure (After Creole Petroleum Corp.)

FIGURE 1—The upper right-hand section of map shows location of the Pedernales region in the Orinoco delta of northeastern Venezuela where field work for the new project was carried out.

Oil is forming in a sand trap only 5000 years old... Studies in northeastern Venezuela have added to the information on...

Oil migration in Recent sediments

By A. L. Kidwell and J. M. Hunt
Research Laboratory, The Carter Oil Company, Tulsa

GEOCHEMICAL STUDIES at Pedernales in Venezuela have prompted a theory of primary oil migration to be added to the growing knowledge of the origin, migration and accumulation of oil.

The Venezuelan studies show that oil can begin to form in a sand trap over 5000 years old. This work has shown that primary migration begins very early, soon after the sediments start to compact. This conclusion is supported by two apparently anomalous observations: the preferential accumulation of aromatics in the trap, and the apparent age of the hydrocarbons is more than twice that of the sand in which it is trapped.

Intensive campaigns are underway by many groups in the petroleum industry to learn more about the origin, migration and accumulation of oil. The development of a few basic principles on the geochemistry of oil occurrence should be regarded as another useful geological tool in finding more oil.

Since hydrocarbons make up more than 90 percent of most crude oils, it is well to examine some of the possible sources for these hydrocarbons. Measurable amounts of hydrocarbons occur in all Recent sediments that were deposited under reducing conditions. Hydrocarbons in minute quantities are common constituents of

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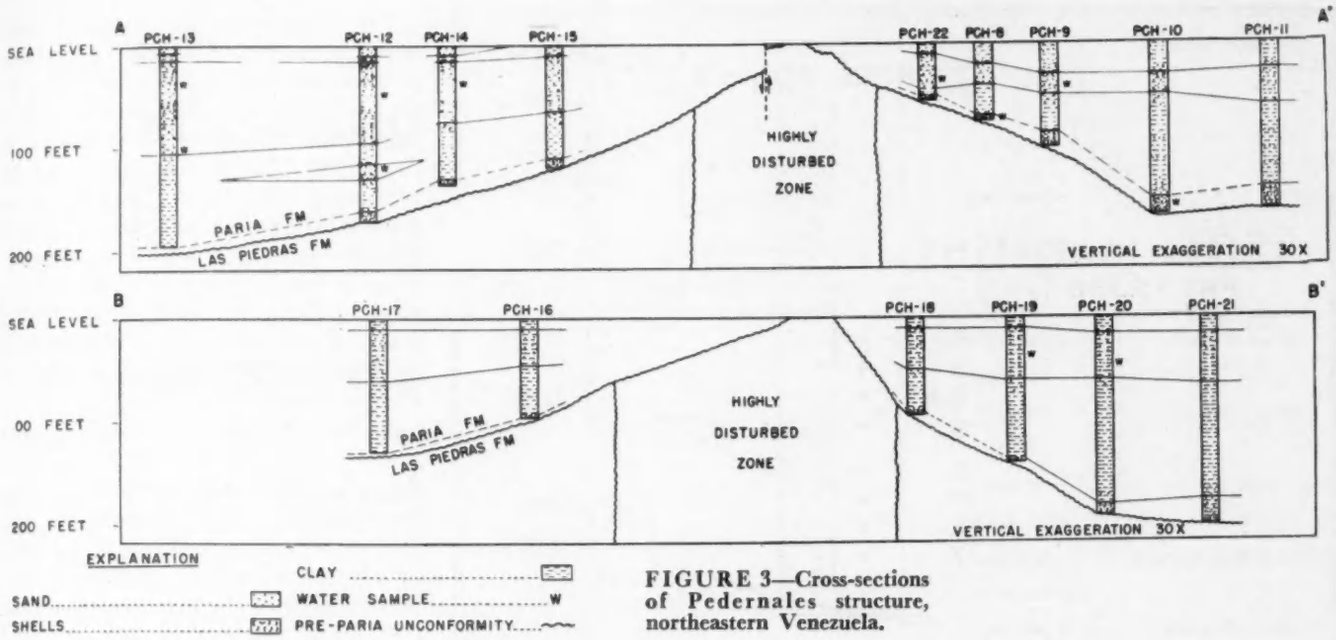

FIGURE 3—Cross-sections of Pedernales structure, northeastern Venezuela.

practically all sediments—recent or ancient. Portions of these hydrocarbons were contributed directly by the organisms that were buried with the sediments because hydrocarbons are formed in all living matter. It is also probable that additional hydrocarbons were produced by certain bacteria feeding upon the original organic matter.

Calculations from a study of Recent sediments taken off Grande Isle, La., revealed there is roughly 4½ million barrels of Recent oil disseminated through each cubic mile of ocean bottom sediments present on the continental shelf.[1] Indications are that this condition also held true in the past.

How and when does this oil begin to migrate out of the Recent sediments and accumulate in the trap? This is the principle of primary migration in contrast to the secondary migration that can take place within a reservoir rock. Discussion in this article will be concerned entirely with primary migration. In this project the authors had hoped to find oil in the process of migration within a section of Recent sediments and find one or more embryonic oil pools in the process of formation.

Geologic Setting. The Pedernales region where the field work was carried out is in northeastern Venezuela in the Orinoco delta (Figure 1). A more detailed map of the Pedernales area is shown in Figure 2. The field work was completed with the cooperation and assistance of the Creole Petroleum Corporation.

Structure sections across the Pedernales anticline are shown in Figure 3. The anticline has a highly disturbed diapiric core that is composed of sandstone and limestone blocks intruded in a plastic shale matrix along a zone of weakness. The disturbed core is shown diagramatically cutting the Las Piedras formation and overlain in part by the Paria formation. The Las Piedras formation is a deltaic sequence of upper Miocene and Pliocene and possibly Pleistocene age. Lithologically it consists of interbedded shales and siltstones that are highly oxidized along the unconformity at the top of the formation.

The Paria formation is all Recent, and the maximum thickness encountered was 200 feet. A sample of carbonaceous clay from the bottom of the deepest hole (No. 13) gave a

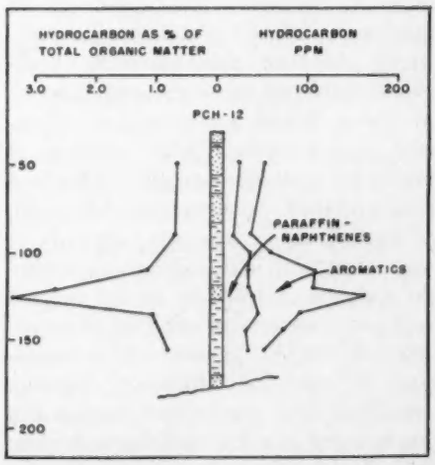

FIGURE 4—Hydrocarbons in Pedernales sand trap.

C-14 age of 9500 years, as determined in the laboratory. This checks very well with the figure of 10,000 years which has been assigned as the age of the last glacial maxima when sea level was considerably lower than at present. In other words, this unconformity was being eroded as recently as 10,000 years ago.

As sea level rose it formed a basal sandy shell bed on top of the unconformity and above this is a rather thick section of featureless gray clay with very little interbedded silt or sand, with the exception of a single sand lens in hole 12. This sand lens will be referred to again later in the discussion. During this time the Orinoco delta was building out toward its present position and the next overlying unit is a typical deltaic sequence. This part of the section starts at the bottom with some silt and sand interbedded with the clay and passes upward into thicker and cleaner sand beds. The uppermost part of the section has been formed within the last thousand years or less after the delta reached its approximate present position.

Fifteen holes were drilled for the samples ranging in depth from 35 to 200 feet at the locations shown on Figure 2. The holes were drilled with a portable rotary drilling rig that could be broken down and carried complete with crew in one large dugout canoe or curiara. One-hundred and fifty cores of the unconsolidated sediments were taken with a three-inch punch-type sampler, which takes a 30-inch length core. These were

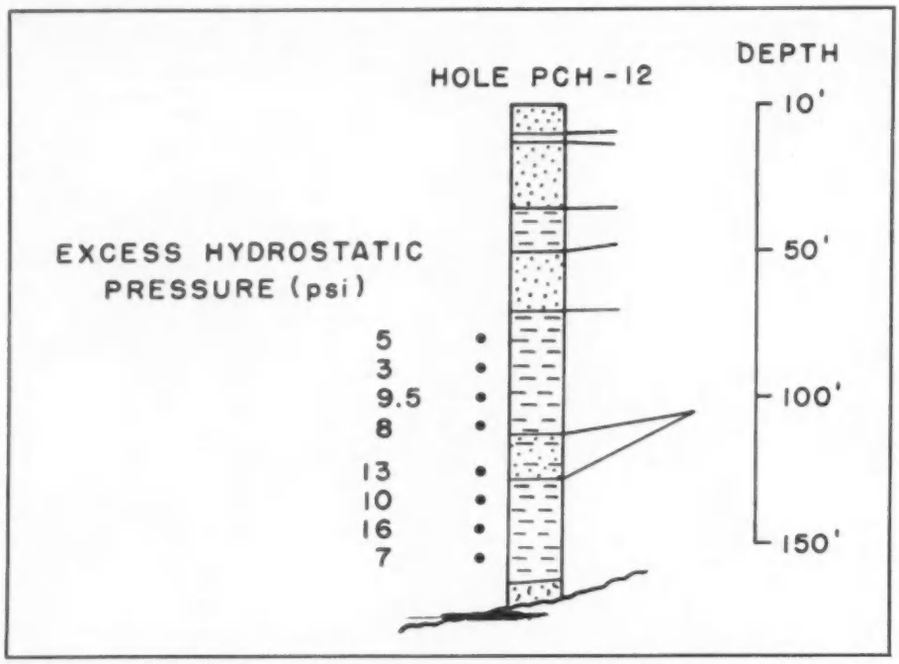

FIGURE 5—Excess hydrostatic pressures in Hole PCH-12.

sealed in the sample tubes and shipped back to the laboratory.

Hydrocarbon Analyses. At this point it is necessary to consider two independent methods of attack to the problem. Is oil starting to accumulate, and, if so, how?

The first method is the actual determination of how much soluble organic matter is present in the samples. The samples were extracted first with acetone to remove the water. They were then refluxed with two solvent mixtures in succession. The extracts were broken down by chromatography over activated alumina into the asphatlic materials, the paraffin-naphthene hydrocarbons and the aromatic hydrocarbons. The results of analyses of samples from hole No. 12 are shown in Figure 4. The hydrocarbon as percent of the total organic matter is plotted on the left. A very sharp increase is shown in and adjacent to the sand body. The hydrocarbons broken down into the paraffin-naphthenes and aromatic fractions are plotted on the right. A slight increase is shown in the paraffin-naphthenes and a marked increase in the aromatics. This phenomena was not observed in any of the other sand beds, all of which reached the surface on the flanks of the anticline and are therefore obviously not traps. A strong flow of methane gas that lasted for several days was also obtained from this sand.

The age of the sand trap based upon C-14 dating of a shell bed overlying the sand is approximately 5000 years. The entire hydrocarbon extract from the sand trap was also sent to the laboratory for C-14 dating. The sample was too small for a reasonably exact determination but it had an apparent minimum age of 14,000 years. A larger hydrocarbon sample was obtained by extracting a composite sample of clay from the section below the sand trap. This was large enough for a reliable date of 13,400 $\pm$ 1200 years. This proves that the hydrocarbons are Recent even though the apparent age is somewhat greater than the age of the sediments as based on wood and shell samples.

Direction of Water Movement. The second method of attack was an attempt to show the direction of movement of the water in the sediments because this probably basic to the problem of when and how oil migrates. When a clay is first deposited, it contains 75-80 percent of water by volume. Any given clay bed will compact with increasing depth of burial, but it can compact only as the interstitial water is squeezed out. At a depth of 190 feet in the deepest hole, the water content had dropped from 80 to 32 percent. This expulsion of interstitial water by compaction is a very convenient mechanism for moving the hydrocarbons present in a highly disseminated state in the sediments.

To determine the direction the water is moving to reach the surface, pressure measurements were made to see if there was any excess hydrostatic pressure in any parts of any of the holes. This was accomplished in two ways. The direct method was to cement a pressure measuring device into the hole and allow it to reach equilibrium over a period of several months. The indirect method was by artificial consolidation of undisturbed core samples using a soil mechanics consolidometer.

Excess hydrostatic pressures were found to exist in the thick clay sections. This is due to overburden pressure which tends to squeeze out the interstitial water and cause consolidation of the clay. However, the permeability of the clay is so low that the consolidation has not reached equilibrium. Consequently part of the overburden pressure is maintained on the interstitial water rather than on the clay particles.

Figure 5 shows excess hydrostatic pressure values measured on samples from hole No. 12 in which the sand trap was found. The values are low near the sand that has surface communication and increase downward through the sand trap and then decrease again toward the somewhat permeable unconformity. Thus, above a certain surface within this section the interstitial water will be expelled upward. Below this surface it will move downward to the unconformity and along it to the surface.

Summary and Theory of Migration. The following summary lists the observations that are pertinent to the problem of oil migration in the Recent sediments at Pedernales:

- A sand trap is present in which hydrocarbons are selectively being concentrated. The apparent age of the hydrocarbons is about 14,000 years.
- The age of the sand trap is about 5000 years.
- Small amounts of hydrocarbons are present in all samples analyzed. They are presumably distributed through the entire section of Recent sediments.
- Interstitial water in part of the clays below the sand trap is moving upward through the sand trap and on to the surface.

The authors believe the most plausible theory as to the mechanics of

Continued on Page 88

Wyoming oil prospects are good

New geological concepts stimulate exploration . . . point to bright future

ERA	PERIOD	FORMATION	OIL-PRODUCING SAND
CENOZOIC	QUARTERNARY	GLACIAL DEPOSITS	
	PLIOCENE	NORTH PARK	
	MIOCENE		
	OLIGOCENE	WHITE RIVER	
	EOCENE	WASATCH	WASATCH SANDS
	PALEOCENE	FORT UNION	FT. UNION SANDS
MESOZOIC	CRETACEOUS	LANCE	MESAVERDE SANDS
		MONTANA GROUP	SUSSEX SAND SHANNON SAND
		NIOBRARA	
		FRONTIER	FRONTIER SANDS
		MOWRY	
		MUDDY	MUDDY SAND
		THERMOPOLIS	
		CLOVERLY	DAKOTA & LAKOTA SANDS
	JURASSIC	MORRISON	
		SUNDANCE	SUNDANCE SAND
	TRIASSIC	CHUGWATER	CROW MTN. SAND
		DINWOODY	
PALEOZOIC	PERMIAN	PHOSPHORIA	PHOSPHORIA LIME (EMBAR)
	PENNSYLVANIAN	TENSLEEP	TENSLEEP SAND
		AMSDEN	DARWIN SAND
	MISSISSIPPIAN	MADISON	MADISON LIME
	DEVONIAN	DARBY	
	ORDOVICIAN	BIG HORN	
	CAMBRIAN	GALLATIN	
		GROS VENTRE	
		FLATHEAD	FLATHEAD SAND

FIGURE 1—Table showing standard geological time, representative formations in Wyoming and oil-producing sands.

By Dr. Horace D. Thomas
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PETROLEUM EXPLORATION in Wyoming has been stimulated by the elimination of certain ideas which dominated geological thinking for many years.

The belief that accumulation could be only anticlinal has been proven invalid through the discovery of fields where oil and gas have been found in other types of traps. The theory that rocks at depths greater than 7,000 or 8,000 feet would be impervious, has not been sustained by fact. The idea that most of the oil sands were essentially blanket sands, without pinchouts or permeability changes, was a false one. Fault traps, long looked upon with disfavor, have proved productive.

General geology. The geological history of Wyoming is a long and complicated one, and no more than a general summary can be presented here. A more comprehensive discussion exists in the published literature.[1] This history, involving episodes of subsidence and deposition, or of deformation, with uplift and erosion, is intimately related to the occurrence of petroleum in the state.

Wyoming was not always characterized by the extremes in relief observable today, with the Tetons towering a mile above the floor of Jackson Hole to an elevation of 13,766 feet, or any of the other mountain ranges rising high above the bordering basins. There is more than 10,000 feet difference in elevation between the lowest point in Wyoming, in the northeast corner, just north of the Black Hills, and the highest point atop Gannett Peak in the Wind River range. At various times in the geologic past the state was a nearly featureless plain. Furthermore, it was a sea-bottom far longer than it has been a mountainous region. In the over-all history, the present relief originated at a moderately late date.

In a simple fashion, Wyoming is made up of downwarped basins which are separated from each other by mountain ranges. These basins are generally flat-floored and lie at elevations of from 4,000 to 7,000 feet. Examples that may be cited are: the Powder River Basin of northeastern Wyoming, lying between the Black Hills and the Big Horn Mountains; the Big Horn Basin of northern Wyoming surrounded by the Big Horn, the Owl Creek, and the Absaroka Mountains; the Wind River Basin of central Wyoming lying between the Wind River, the Owl Creek, and the Big Horn Mountains; the Laramie Basin of southeastern Wyoming lo-

cated between the Laramie Range and the Medicine Bow Mountains; and the Green River Basin of southwestern Wyoming, lying between the Wind River and the Wyoming ranges. Geologically, the mountain masses are great upwarps of the earth's crust; the basins are major downwarps.

The basins, for the most part, are not simple drainage basins. The major rivers of Wyoming have the peculiar habit of rising in one mountain range, flowing through an adjacent basin and then surprisingly cutting directly across one of the other bounding mountain masses. The Laramie River flows northward through the Laramie Basin, then makes a right-angle turn and cuts directly across the Laramie Range. The North Platte River flows across the Seminole Mountains, the Granite Ranges, Casper Mountain and the Hartville uplift before it leaves the State. The amazing Wind River flows through the Wind River Basin, across the Owl Creek Mountains, across the Big Horn Basin and thence across the Big Horn Mountains.

Geological history. The oldest rocks in Wyoming are composed of crystalline igneous and metamorphic rocks, among which granite is the most common, and collectively are appropriately called the "basement complex." These ancient rocks, some of which are more than 2 billion years old, reveal an inconceivable long history of volcanic activity and of crustal deformation. Mountains which existed before life appeared on this planet were eventually worn down to an almost featureless surface. The pre-Cambrian rocks constitute the foundation on which a great thickness of sedimentary rocks was subsequently deposited, and are exposed in the cores of all the typical mountain ranges of the state.

At the beginning of Paleozoic time, some 520 million years ago, the Rocky Mountain region was quite different in its physical aspects from those observable today. A great subsiding trough, existing to the west of Wyoming, was occupied by seas and was the site of deposition for great thicknesses of sediments derived from adjacent land masses, or which originated as chemical and biological precipitates from marine waters. Wyoming occupied a more stable area which bordered this trough on the east. It was not so rapidly subsident, nor did such great thicknesses of sedimentary rocks accumulate, nor was it so often covered by seas. Indeed, the southeast part of Wyoming remained emergent and above the seas until well along toward the close of Paleozoic time.

Many of these Paleozoic rocks produce oil in Wyoming (Figure 1). The oldest one, the Cambrian Flathead sandstone, produces in the Lost Soldier and Wertz field; the Ordovician Bighorn dolomite produces in the Hamilton field; the Devonian limestones produce in the Byron field; the Madison limestone, of Mississippian age, produces over wide areas; the Tensleep sandstone, of Pennsylvanian age, is perhaps the most important oil producer in the state; and the Permian dolomite (Phosphoria formation), deposited near the end of the Paleozoic era, is an important producer through the western half of Wyoming.

The Mesozoic era began about 200 million years ago and at the outset the physical setting was not markedly different from that of the Paleozoic. Again the major seaway was west of Wyoming and marine Thaynes limestone, of Triassic age, was deposited there. Over most of Wyoming, however, there was deposition of a conspicuous set of bright red shales and sandstones, the Chugwater formation. At about this time, however, crustal unrest in the region west of Wyoming resulted in the deformation and uplift of the old subsiding trough and the formation of new mountains. This event completely changed the physical features of the region. During Jurassic time, a sea, teeming with marine life, spread over Wyoming from the north, and sandstones and shales of the Sundance formation were deposited. As this sea withdrew, a low marshy plain was developed, whose main inhabitants were dinosaurs, as attested by the abundance of dinosaurian fossils in the Morrison formation. With the advent of Cretaceous time, Wyoming itself became a subsiding trough in which tens of thousands of feet of marine and terrestrial sediments were deposited. Their source lay in the rising mountain mass which then bordered the state on the west. Volcanoes in this mobile belt spewed volcanic ash into the Cretaceous sea. These ash deposits have subsequently been altered to bentonite, a colloidal clay now useful as drilling mud and in other ways. The withdrawal of this sea led to the development of coastal plain swamp deposits and associated coal beds.

The growth of the Rocky Mountains apparently began late in Cretaceous time, about 70 million years ago. Compressive forces operating on what is now Wyoming resulted in the uplift of the mountain axes and the relative depression of the basins. The great anticlines, of mountainous proportions, were overturned, fractured, faulted and greatly complicated. The resulting basins were not simple downwarps but within them developed minor anticlines and faulted structures. This mountain-making activity was not catastrophic but proceeded slowly over millions of years. By the end of Cretaceous time the major structural elements of Wyoming had come into being, but the landscape was further modified by crustal deformation in early Tertiary time.

The Mesozoic rocks are also important as oil producers. The Crow Mountain sandstone, of Triassic age, produces in central Wyoming. The Jurassic sandstones produce in a northeast-southwest belt in southeastern Wyoming along what had been the ancient Jurassic shoreline. The Cretaceous rocks are productive in every oil-producing county in the state, and there are numerous producing sands.

As soon as the mountains were raised above the basins, erosion began to attack their crests. Sediment derived from the mountains was deposited by streams in the basins. The older Tertiary rocks are largely stream and swamp deposits, containing thick coal beds, but a great fresh water lake formed in the Green River Basin and in adjacent northwestern Colorado. In it the Green River oil shales were deposited.

The Yellowstone Park region became a volcanic center early in Tertiary time. The hot springs, geysers and other phenomena visible today are simply evidence of the dying stages of volcanic activity. The rocks at the surface are lava flows and accumulations of volcanic bombs and ash which buried all the older rocks. Indeed, volcanic ash from the Yellowstone center blanketed much of Wyoming during middle and late Tertiary time. These ash deposits carry small amounts of uranium, and commercial uranium deposits in Wyoming appear to have resulted from concentrations

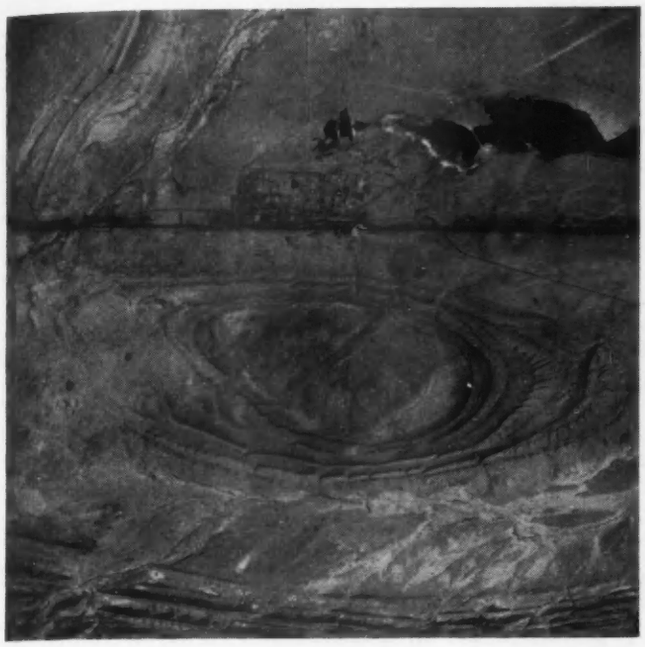

FIGURE 2 — Air photo of a typical Wyoming "sheepherder anticline." Although Grenville dome is unproductive it is an excellent example of the sort of well exposed structure on which many of the early Wyoming fields were discovered. The refinery at Sinclair, Wyo., lies just north of the dome.

Photo courtesy U. S. Geological Survey

of uranium reached from the ash deposits.

During middle Tertiary time, many of the basins were essentially filled with sediment, so that streams flowing across their surfaces were able to find courses across buried mountain ranges. Later uplift caused these streams to cut downward and, having established their courses, they were forced to excavate canyons across the previously buried mountains.

Wyoming again underwent growing pains during later Tertiary time. Faulting and uplift took place over most of the state. At this time the majestic Teton Range came into being as the result of a great fault 40 miles long with 20,000 feet of displacement. The precipitous mountain front is in part related to its youthfulness.[2]

Quaternary time was one of glaciation. The rugged nature of the mountains is largely due to the erosive action of ice masses in the higher elevations which flowed as valley glaciers down the previously cut canyons. In only a few areas did the glaciers reach the basin floors.

Thus we are brought to the present snow-capped mountains, the sagebrush deserts and the land as seen today.

Petroleum geology. Petroleum production in Wyoming is interesting in many ways. There have been 200-barrel wells producing from sands as little as 265 feet deep. Conversely, there has been production from a sand deeper than 16,000 feet in the West Poison Spider field. The productive sand at that depth is exposed at the surface only a few miles northwest of the field. There is commercial production from sands as old as Cambrian and as young as Tertiary, representing every geological period except Silurian and Quaternary. There is one field, Lost Soldier, in which there are 14 distinct reservoirs ranging downward from Cretaceous to Cambrian. Even the weathered pre-Cambrian granite below the sedimentary rocks is oil-saturated. All but two counties of the 23 produce oil, and there is no good reason why the other two should not produce ultimately. There is a dry hole which was drilled to a depth of 20,520 feet, bottoming in Cretaceous rocks and with the granite lying 10,000 or more feet below the bottom of the well. Yet from the wellsite granite can be seen cropping out on the flank of the Wind River Mountains only 10 miles away. There are some producing anticlines in which the beds on one flank have been deformed from their original horizontal position to stand vertically or overturned.

Wyoming is one of the oldest and one of the more important oil-producing states. The first productive wells were drilled in the 1880's, and since that time the state has produced over 1.5 billion barrels of oil. The year 1957 was marked by a record production of 107 million barrels of oil, and Wyoming ranked sixth among the oil-producing states. Nearly 200 different fields are productive. The present proved reserves are about 1.6 billion barrels and have essentially doubled in the past seven years.

In the discussion to follow, it will be necessary to refer to structural traps and stratigraphic traps. Structural traps are those in which oil has accumulated because of deformation —folding or faulting, or a combination of both. The conventional "oil dome" in Wyoming is an anticlinal structure in which the beds have been arched upward and oil has accumulated in the crestal part of the upwarp, floating on a water table. Faults are dislocations of the earth's crust, and where they displace porous reservoir beds so that these beds abut against impervious beds, they may similarly trap oil. In the case of stratigraphic traps, factors other than structure are most important and are generally associated with variations in beds as originally deposited. Sands may pinch out up-dip or grade into impervious shale, or porous limestone may change to dense limestone, so that permeability barriers are established. Oil may migrate into these beds but cannot proceed up-dip beyond the permeability barrier.

The first oil produced in Wyoming came from seeps and was used in the 1840's to grease the axles of wagons traversing the Mormon Trail, or for purposes of medication on oxen. The first producing well was drilled in 1884 in the Dallas field, Fremont County, near an oil seep noticed in 1833. It happened that the Dallas oil seep was located along the crest of the Dallas anticline, and thus the first oil produced from a well in Wyoming was from an anticlinal trap. This old field produced about 168,000 barrels of oil in 1957.

Oil seeps were known in the vicinity of the Salt Creek field before 1880, and in 1889 a well drilled down-dip from an outcrop of oil saturated sand around the Salt Creek anticline discovered the Shannon pool. The second field, then, would be classed as a stratigraphic trap. When the first big producer was drilled on the crest of the anticline, resulting in the discovery of the Wall Creek sand production in the famous Salt Creek field, which to date has produced about 365 million barrels of oil, the Shannon pool and stratigraphic traps faded into oblivion. Other anticlines early proved productive. By 1916 such fields as Big Muddy, Elk Basin, Garland, Grass Creek and Lost Soldier, all anticlinal in nature, had been discovered.

Thus the search for anticlines began. Many of them are beautifully

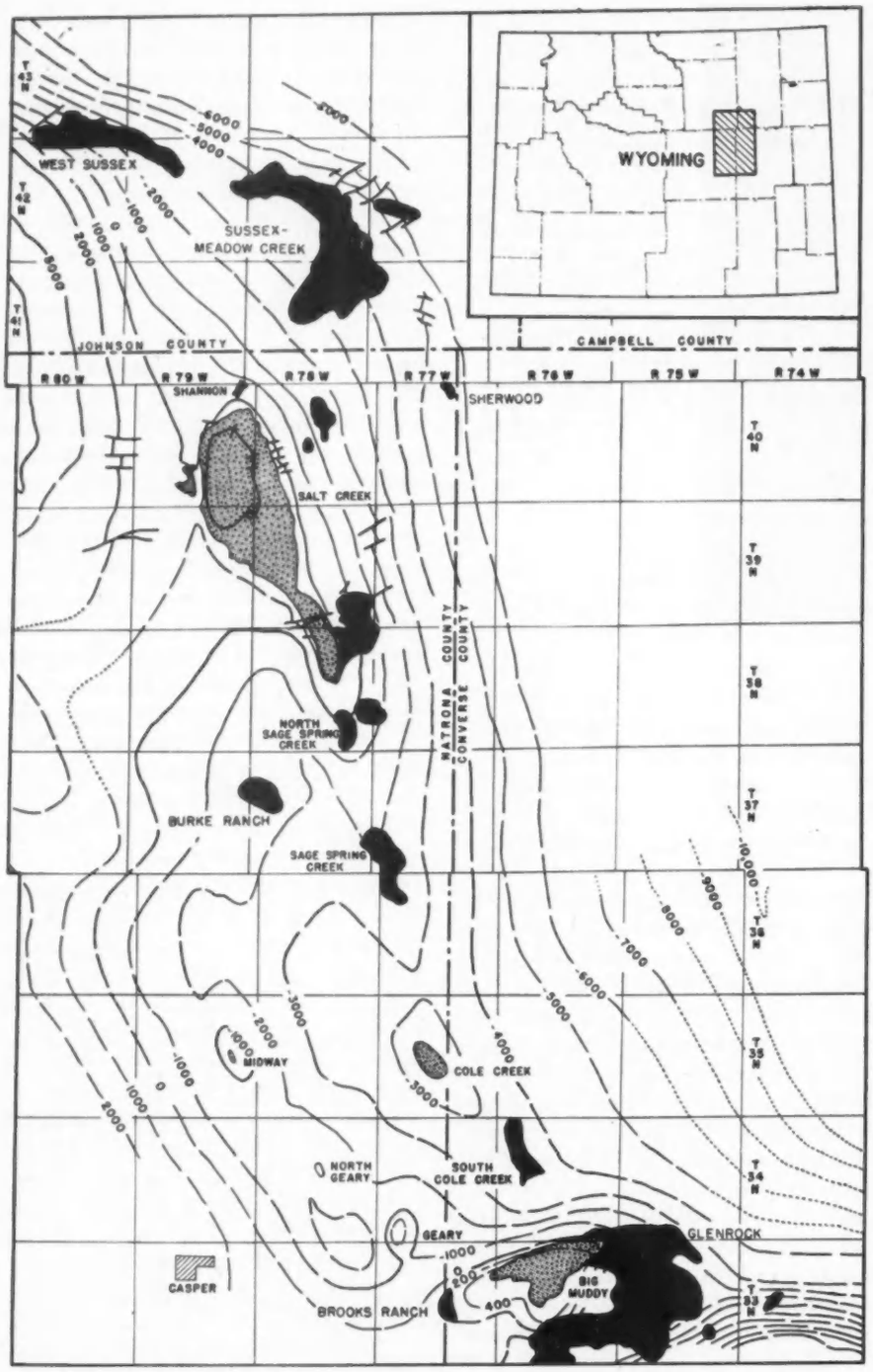

FIGURE 3—Map of the Salt Creek-Big Muddy area on the southwest flank of the Powder River Basin. Fields discovered before 1948 (Salt Creek, Cole Creek, and Big Muddy) are shown in a stippled pattern. Fields which have been discovered since 1948 are shown in black. Structure contours are drawn on the Cloverly formation.

exposed and encircled by escarpments. This type became known as "sheepherder structures" because it was felt that even a sheepherder could recognize one (Figure 2). The main tool was surface mapping, and for years geologists mapped the basin margins searching for unknown structures, and many were found. Wyoming fields became known as classic examples of the anticlinal accumulation of oil and gas.

Exploratory wells drilled on newly discovered anticlines were carried to such depths as were then economically feasible or mechanically possible. Some resulted in the discovery of new fields; many were dry holes. Eventually most of the anticlines had been mapped, but obviously surface mapping as an exploratory tool proved less and less effective.

About this time certain geological prejudices began to arise which completely governed exploratory thinking. Briefly, some of these were:

- Only anticlines could be productive.
- Anticlines must have at least several hundred feet of closure.
- There were only certain formations which could produce and that there was no use drilling to deeper ones.
- All the sandstones were blanket sands.
- Sandstones below depths of 6,000 or 7,000 feet would be devoid of porosity.
- Numerous other ill-founded and fallacious precepts.

To expand reserves there were two recourses, first, to drill deeper on anticlines which produced from shallow sands or which had proved barren in shallow sands, and second, to search by geophysical means for anticlines covered by the younger underformed Tertiary strata which occupy the central parts of the basins. Some anticlines, like Elk Basin, which had been modest producers from shallow sands, were prolific producers from deeper sands. This field was discovered in 1915, but it was not until 1942, 27 years later, that a well was carried to the Tensleep sand at a depth of only 4,500 feet. In its 41 years as a producer, only 14 million barrels of oil have been produced from the shallow sands. The deeper Tensleep reservoir has yielded 96 million barrels in the past 15 years. Some anticlines which yielded gas from shallow sands yielded oil from deeper sands. Other anticlines which had been barren in shallow sands produced oil from deeper sands. Although deeper drilling has been important in the development of new pools on anticlines which had not previously been tested deeply, it is apparent that there is a limited number of known anticlines subject to deeper drilling. Ultimately the day will come when every known anticline will have been tested down to the granitic basement complex.

When surface geology had lost much of its effectiveness in locating untested anticlines, the seismograph came into importance—again seeking anticlines, but this time buried ones not expressed at the surface. The first seismic discovery was made in 1934, and the technique has paid dividends through the finding of many fields which are classed strictly as geophysical discoveries. Because of the great size of the basins, and through improvements in technique, more fields

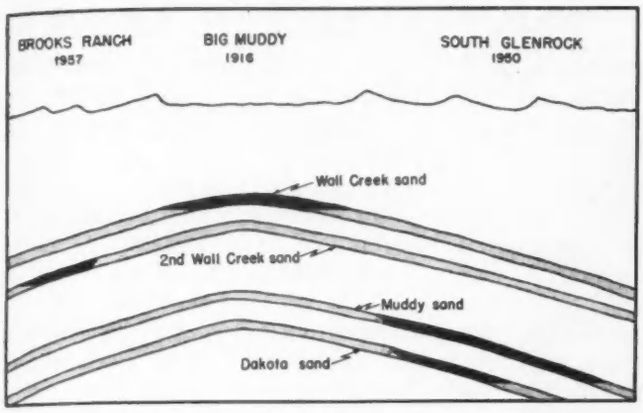

FIGURE 4—Diagrammatic cross-section through the Brooks Ranch, Big Muddy and South Glenrock fields. The anti-clinal pool was discovered in 1916. The South Glenrock and Brooks Ranch pools are trapped by up-dip permeability barriers.

will surely be found through geophysical methods.

Naturally, during the search for producing anticlines, many wells were drilled "off structure" and resulted in dry holes. It now appears that some may not have been drilled far enough "off structure." One thing which should be emphasized today is that important discoveries have been made in recent years through wildcat wells drilled in locations which the early day Wyoming geologist would have thought ridiculous. Fields are being discovered in regions tramped over by generations of geologists and condemned as "off structure." Oil is being found in areas where no anticline can be mapped at the surface or plotted by seismograph. And this is important, for a vast area which once had been thought to have no promise has become prospective oil territory.

New exploratory-discovery trends. As an example of the new exploratory and discovery trends in Wyoming, the area embracing the old Salt Creek, and Big Muddy fields, lying along the southwest margin of the Powder River Basin, has been selected (Figure 3). The Salt Creek field, discovered in 1906, lies in the northern part, and the Big Muddy field, discovered in 1916, lies in the southern part. Until 1938 these were the only two fields within the area considered. In 1938, on the basis of seismic work, the Cole Creek field was discovered. This field is anticlinal and lies about midway between the Salt Creek and the Big Muddy fields. In 1948 seismic exploration led to the discovery of anticlinal production at South Cole Creek. For over 40 years, therefore, the search in this region had been for anticlinal production, first through surface mapping and later by seismic surveys. Only a few years ago, it might have been said that since all the anticlines had been found, the petroleum producing potentialities of the area were fairly well exhausted.

It is evident now that such a pessimistic forecast would not have been valid. During the past nine years, 14 producing fields have been found within this area, but not one is a conventional pool on the crest of a surface anticline. These 13 fields have produced about 60 million barrels of oil, and most of them are still being developed. Reserve figures are not available, but they must be large.

Five fields have been discovered since July, 1948, in the Sussex-Meadow Creek area on the northeast flank of the large Salt Creek anticline. If a well had been drilled in this region in earlier days, it would have been classed as "off structure." Six different sands have proved productive, one of which—the Sussex sand, was not known to be an oil producer until these fields were discovered. Production has amounted to over 33 million barrels, and development drilling is still under way. None of these fields fits the concept of what used to be considered an orthodox Wyoming oil field. There are no surface anticlines. Trapping is related largely to faulting, to folding not expressed at the surface and to variations in the sand bodies.

East Salt Creek lies on the east flank of the Salt Creek anticline, and again there is no surface anticline. It was discovered in 1951, but in 1956 a discovery well drilled to a deeper pay flowed 1,944 barrels of oil per day.

Two fields, Sage Spring Creek and North Sage Spring Creek, were discovered in 1949 on the south plunge of the Salt Creek anticline in an area which in earlier days would have been considered "off structure" and below the water table. Accumulation is controlled by a porous sand becoming impermeable up-dip, and the producing sand lies about 4,600 feet lower structurally than in the Salt Creek field. Over 4 million barrels of oil have been produced in an area condemned by earlier day geologists.

Discoveries in the southern part of the area, around the old Big Muddy field, are of great importance. In 1915 the Big Muddy anticline and the surrounding region were mapped by a federal geologist. In his published report[3] he remarked that the U. S. Geological Survey was constantly searching for domes as an aid to prospectors. He said, "Although the survey does not guarantee that oil will be found in any of these domes, its position is that domes are the most promising localities; and if the drill proves that they do not contain oil, it is useless to search in other places."

The Big Muddy field, an anticlinal trap, was discovered in 1916. It has been one of Wyoming's more important producers, having produced about 40 million barrels of oil. In 1935 a deep test was drilled on the crest of the dome and was carried to the Madison limestone. No deeper production was developed, and at that time it appeared that the future of the Big Muddy area would be one of decreasing production and eventual abandonment.

It was not until 34 years after the discovery of the Big Muddy field that a well was drilled "off structure" for geological reasons. It discovered the South Glenrock field, just east of Big Muddy and outside the lowest closing contour of the Big Muddy anticline (Figure 4). Well over 100 development wells were completed before the first dry hole was drilled. The Glenrock and South Glenrock fields are both stratigraphic type traps, and production is from sands which become impervious updip.[4] The fields have produced over 20 million barrels of oil and are just reaching their full potential.

The Brooks Ranch field, on the western plunge of the Big Muddy anticline, was discovered in 1957. Again, an "off-structure" well found production in a sand which becomes dense and impermeable on the crest of the anticline. Development drilling is still underway, but geological implications are that over 3,000 acres will prove productive.

So far as this general region is concerned, then, 14 fields have been

found in an area which once was thought to have been fully explored and to have no further possibilities for petroleum production.

Other non-anticlinal fields in northeastern Wyoming have attracted attention in recent years. These are the Mush Creek, Fiddler Creek, Skull Creek, Lodgepole and Clareton fields. Production is from a westward-dipping sandstone which loses its permeability up-dip. The Clareton field, since its discovery in 1950, has produced over 13 million barrels of oil.

A good example of an "off structure" stratigraphic type field is the Cottonwood Creek field, discovered in 1953, in the Big Horn Basin. It lies immediately southwest of the anticlinal Hidden Dome field, discovered in 1917. It was known that the Phosphoria dolomite, which produces oil in fields to the west, is dense and impermeable in wells drilled in the vicinity of the Hidden Dome anticline. Although it took three wells to make the discovery, oil was found to be trapped down-dip from a permeability barrier.[5] Since 1953 the field has been extended three miles south and four miles east of the discovery well, and the down-dip limit of production has not been reached.

The Bonanza field can be used to illustrate the influence of geological prejudices. The Bonanza anticline was mapped prior to 1917 but was not drilled because it lacked adequate surface closure. However, in 1951, at least 35 years after the anticline had been known, a well was foolishly drilled. Since that time over 18 million barrels of oil have been produced.

Another predilection pertained to structures closed only by faulting, and such structures were not considered attractive nor were they drilled. Today, however, many good fields produce from strictly fault traps.

Future outlook. Oil is produced in Wyoming from rocks as old as Cambrian, deposited 500 million years ago, and from rocks as young as Eocene, deposited only 50 million years ago. Within the tremendously thick sedimentary succession, many stratigraphic changes surely have served to trap oil in pools not yet discovered. From time to time, stratigraphic units hitherto not known to produce oil have proved productive, and new ones may join the list of producing units.

Surface exploration will continue significantly in the search for anticlines, for possible fault traps, or for structural anomalies at the surface which may indicate possible traps at depth. Geophysical exploration has proved effective in the search for structural traps in regions covered by undeformed rocks, and large areas are still amenable to geophysical scrutiny. The study of the nature and correlation of rock units and the development of an understanding of the conditions under which they were deposited—that branch of geology known as stratigraphy—will perhaps become the most important exploratory method.

It is apparent that the diverse ways in which oil and gas are now known to be trapped have greatly enhanced the petroleum possibilities, and simple anticlinal production is by no means the only potential. Obviously, for many years the lion's share of production will continue to be from anticlinal fields. It is good to know, however, that the search for oil in Wyoming may well continue profitably far beyond the time of the drilling of the last possible anticline.

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About the Author

Dr. Horace D. Thomas is the author of papers on stratigraphy, regional geology and petroleum resources of the Rocky Mountain region. He received B.A. and M.A. degrees from the University of Wyoming in 1926 and 1928, respectively. In 1935 he was awarded a Ph.D. from Columbia University. During 1955-56 he was vice president of AAPG and was a distinguished lecturer in 1949 under the auspices of AAPG.

Oil migration in sediments

Continued from Page 82

migration at Pedernales is as follows:

Small amounts of hydrocarbons are present in the organic matter deposited with the muds. Under certain conditions some additional hydrocarbons are probably formed by bacteria. As the thickness of mud or clay builds up, part of the interstitial water is squeezed out carrying wit hit minute quantities of oil that are present in a disseminated state in the muds. The physical state in which the oil moves is somewhat uncertain but it is probably present in the water as an extremely dilute colloidal dispersion. If the fluid passes into a sand bed that has a surface connection, it moves along this sand bed to the surface and is dissipated. However, any of the fluid that enters an enclosed sand body has to re-enter the overlying finer sediments to reach the surface. The water phase of the fluid can pass from a sand back into a water-wet mud but any entrained oil will be filtered out at the first sand-mud interface. Thus, there is a very slow but continual straining action.

Two observations appear to be anomalous. One is the preferential accumulation of aromatics in the trap. It is suggested that the aromatic hydrocarbons may be more mobile than the other fractions and tend to accumulate first.

The other anomaly is the fact that the apparent age of the hydrocarbons is more than twice that of the sand in which it is trapped. Although there is not any sure explanation, it appears that the apparent age of the Recent hydrocarbons has been exaggerated by dilution with some older natural hydrocarbons. The bulk of the material has to be Recent, however, even when allowing for some possibe contamination.

This work has shown that primary migration begins very early, soon after the sediments start to compact. It does not appear necessary to consider the mysterious transformation of organic matter throughout long periods of geologic time when accounting for a large portion of the oil that has migrated into reservoirs.

ACKNOWLEDGMENT

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Application of DST to hydrodynamic studies

Accurate formation fluid pressures vital to hydrodynamic studies in relation to petroleum exploration can be obtained by properly conducted and interpreted drill stem test.

By Dr. H. K. van Poollen and Sam J. Bateman
Halliburton Oil Well Cementing Company, Duncan, Okla.

DUE TO INCREASED interest in stratigraphic traps, application of the principles of hydrodynamics may become an important exploratory tool for discovery of new oil and gas reserves. The most sensitive data required for hydrodynamic studies are accurate formation fluid pressures. The drill stem test has been found to be one of the best methods of obtaining these required pressures. A properly conducted and interpreted drill stem test will provide much important reservoir information concerning potential producing horizons.

In recent years, most leading exploration geologists and geophysicists have agreed that the stratigraphic trap may be the key to providing new reserves. It also is realized that a drastically new method of exploration is needed if the greater number of these traps are to be found. One method of exploration, though not well known, is the application of hydrodynamics.

Many theories have been suggested for the origin of petroleum. However, practically all imply an originally widely scattered occurrence of the oil and gas. Subsequently, these materials must have been subjected to certain forces which resulted in commercial concentrations.

In essence, to reach equilibrium,

FIGURE 1—Fundamental hydrodynamic relationships are illustrated. Fluid will tend to move from left to right in the example shown, since it will tend to move from a higher to a lower potential.

h = Height of potentiometric surface above datum plane.
p = Fluid pressure measured at elevation "z" above datum plane.
ρ = Density of fluid
g = Acceleration due to gravity
ϕ = Potential

FIGURE 2—The relationship between the potentiometric surface and the tilt of the oil-water interface is shown. Note the considerably different tilts possible for different gravity oils.

$\frac{dhw}{dx}$ = Tilt of potentiometric surface
θ_c = Tilt of oil-water interface
ρ_w = Density of water
ρ_o = Density of oil

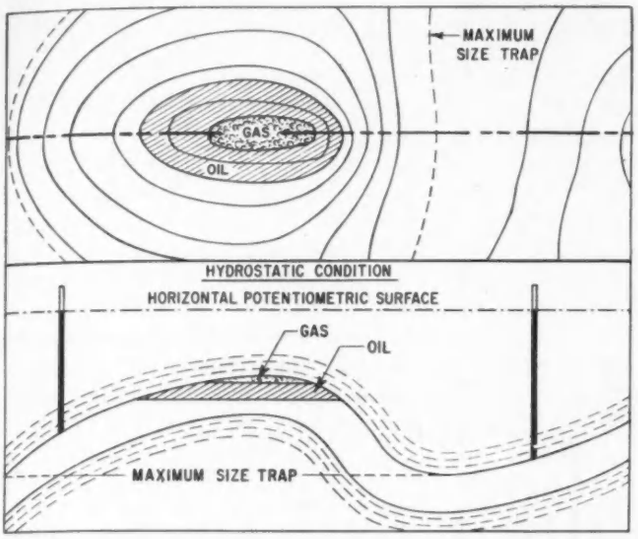


FIGURE 3—The hydrodynamic gradient shown is zero and the potentiometric surface is horizontal. This illustrates the hydrostatic condition (no fluid motion).

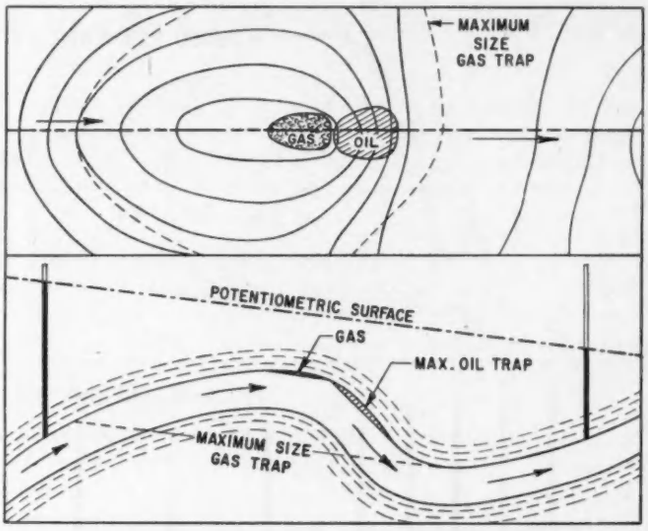


FIGURE 4—Here the hydrodynamic gradient has been increased. With a steeper gradient the oil trap would vanish entirely. In certain areas only gas may be found or otherwise favorable structures may result in dry holes.

each particle would tend to move to a location where its potential would be at a minimum. It is evident that to accomplish this, oil and gas particles may have moved over considerable distances. If the hydrostatic condition is assumed, it follows that oil globules will move up-dip and continue to do so until trapped in the highest point in a stratum against an impermeable boundary. Unless the oil-containing stratum is covered by a continuous cap rock, the oil will escape to overlying formations. Gas, being lighter than oil, will tend to move through water and oil under the same hydrostatic forces.

Thus, it will eventually accumulate on top of the oil; the surfaces between gas and oil, and between oil and water will be horizontal planes. Following this trend of thought, exploration geologists have searched for anticlines, domes, faults, unconformities, salt domes and other stratigraphic traps in general.

In certain areas, it has been found that otherwise favorable structures are barren. A more thorough study and understanding of hydrodynamic conditions will aid in explaining why these structures do not contain petroleum. In many instances, observations have been made of tilted water tables and asymmetrical arrangements of oil, gas and water. Gas also has been found up structure from water where oil occurred down structures from the water.[4] One, and possibly the only explanation for such deviation from classical acceptance of oil traps, is that the water is not in a hydrostatic but in a hydrodynamic condition.

The physical theory and the equation of tilt of the interface between a flowing underground fluid and a static one were first derived by Hubbert (1940, p. 864-873).[1] Other investigators have further elaborated on the principles of hydrodynamic entrapment.[3, 4, 5, 6]

Principles of hydrodynamics. The major premise of hydrodynamic entrapment is that all particles will tend to move to a region where their potential energy is the lowest. Thus, oil and gas will come stably to rest in any region (petroleum trap) which is surrounded by higher energy levels and impermeable barriers. Next, the assumption is made that petroleum migration occurs in a ground-water environment. Since it is possible to determine the energy field in terms of the ambient aquifer water, the energy fields for petroleum will be expressed in those of the water.

Water tables will tend to approach a horizontal upper surface since potential energy is at its lowest everywhere under these conditions. However, they usually follow the earth's topography quite closely. It may be concluded that ground water is not in equilibrium and that it moves. Water is repeatedly added at the earth's surface by precipitation. This also tends to disrupt equilibrium and keep the water in motion.

Ground water potential. An element of water at any point possesses a potential energy with respect to its environment. When referred to unit mass, it is called potential ϕ. If ϕ were the same at all places, no movement would occur. On the contrary, if a difference in potentials exists, water will try to take the shortest route to the point of lower potential (Figure 1). Thus, it can be imagined that equipotential surfaces exist which are perpendicular to a stratified formation through which water moves parallel to the bedding plane. It can be shown that a certain point, the potential $\phi = gz + \frac{P}{\rho}$ where "g" is the acceleration of gravity, "z" the point elevation with respect to a certain plane (usaully sea level), "P" the gage pressure at the point considered, and "ρ" the density of the fluid in the acquifer.

If the point in the aquifer were connected with an imaginary tube, fluid would rise in this tube to a point "h" above our datum plane, i.e., sea-level. The potential can then be expressed as: $\phi = gz + \frac{\rho g(h-z)}{\rho} = gh$. The potential, with respect to datum of an element thus becomes equal to the work required to lift a unit mass the height "h" against the attraction of gravity. The rise "h" above datum in the imaginary tube is calculated rather than measured by the equation: $h = z + \frac{P}{\rho g}$. (Figure 1)

If the value "h" is determined at

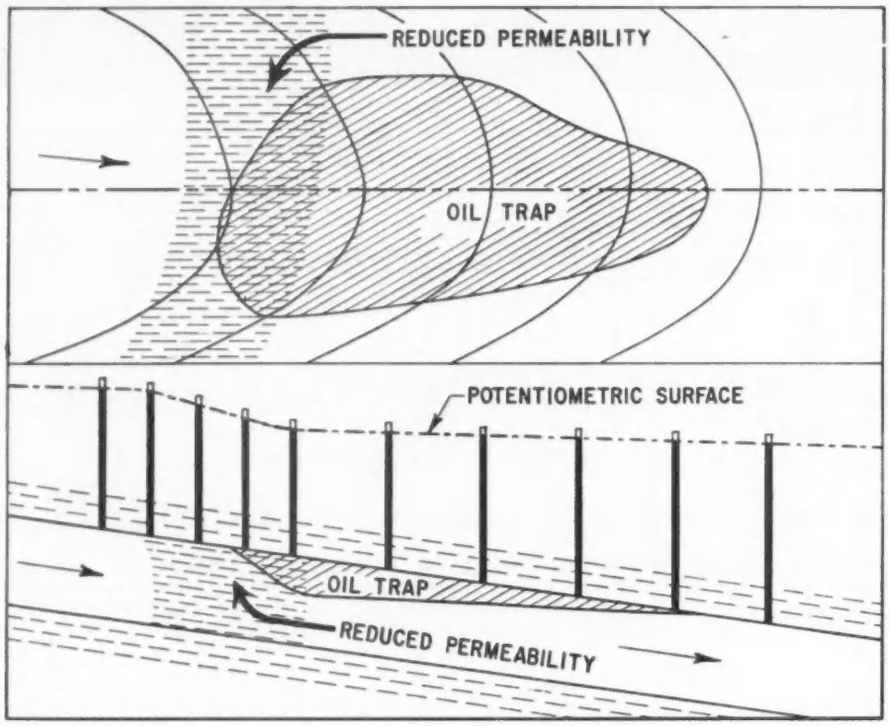


FIGURE 5—This is an example of a trap which may be overlooked without the knowledge of hydrodynamics. Shown is a zone of reduced permeability which may be detected by a suddenly increasing hydrodynamic gradient. The oil equipotential surfaces will have the shape of a trough. (Redrafted from Hubbert—1953—A.A.P.G. Vol. 37, No. 8.)

different locations throughout an aquifer (on the upper surface of the stratum) and points plotted above each location, a surface can be passed through these points. This surface is called the potentimetric surface or piezometric surface.

Significance of the potentiometric surface. Fluid will flow nearly perpendicular to the equipotential lines (contours) on its potentiometric surface. It will move from the highest potential to the lowest. If the potentiometric surface is a flat, horizontal plane, there will be no motion and the hydrostatic condition exists.

The potentiometric surface usually is a flat plane in the case of most aquifers where a sand is bounded below and above by impermeable shales. Therefore, three points which are not on a straight line usually should be sufficient to determine the potentiometric surface.

Oil potential and trap. Ignoring capillary pressure effects, it can be shown that the potential of oil is equal to $\phi_o = gz + \frac{P}{\rho_o}$ in which ρ_o is the density of the oil. The potential of water, as was shown above is $\phi_w = gz + \frac{P}{\rho_w} = gh = g\left(z + \frac{P}{\rho_w g}\right)$ which can readily be measured and calculated. Combining the above equations, it follows that $\phi_o = \frac{\rho_w}{\rho_o} \phi_w - \frac{\rho_w - \rho_o}{\rho_o} gz$. By substituting $\phi_o = gh_o$ and $\phi_w = gh_w$ it follows that $h_o = \frac{\rho_w}{\rho_o} h_w - \frac{\rho_w - \rho_o}{\rho_o} z$. Furthermore, it can be shown that the tilt of the oil-water interface will be

$$\tan \Theta_c = \frac{dz}{dx} = \frac{\rho_w}{\rho_w - \rho_o} \frac{dhw}{dx}$$

in which $\frac{dhw}{dx}$ is the slope of the water-potentiometric surface (Figure 2).

The interrelated water and oil potentials which exist in the aquifer will result in *water* equipotential planes and *oil* equipotential planes. The oil equipotential planes will intersect the top of the formation along certain lines. The line of intersection which forms a closure and has the highest potential value will be the lower boundary of an oil trap since oil will only be able to flow to a lower potential. The closure is necessary to confine the petroleum.

To obtain the outline of an oil trap, the following graphical procedure may be of help. The oil potential

$$\phi = \frac{\rho_w}{\rho_o} \phi_w - \frac{\rho_w - \rho_o}{\rho_o} gz, \text{ or } h_o = \frac{\rho_w h_w}{\rho_o} - \frac{\rho_w - \rho_o}{\rho_o} z$$

which can be written as

$$\frac{\rho_o}{\rho_w - \rho_o} h_o = \frac{\rho_w}{\rho_w - \rho_o} h_w - z$$

which has the form $u = v - z$. The constant values of "z" are the contours of the structural map on top of the formation. The constant values of "h_w" are the contours of the water potentiometric surface and "v" the contours of $\frac{\rho_w}{\rho_w - \rho_o} h_w$. The intersection of "z" and "v," which will give constant values for "$v - z$" can now be connected. The lines thus obtained have the value of $\frac{\rho_o}{\rho_w - \rho_o} h_o$ and are directly proportional to the oil potential. The lower boundary of an oil trap is outlined by any line of intersection which forms a closure. Gas traps may be found in a similar manner, if certain small errors are allowed by treating gas as a fluid. A more complete description of the above may be found in the literature[4] (Figures 3, 4 and 5).

Pressures. Besides measured and/or assumed values of "ρ_w" and "ρ_o" for the densities of the water and the oil, the most important data are the aquifer pressure "P" and the elevation "z," at which it was measured. This can be observed in the basic equations $h_{xy} = z_{xy} + \frac{P}{\rho_w g}$ which describes the potentiometric surface, and $\tan \Theta_c = \frac{\rho_w}{\rho_w - \rho_o} \frac{dhw}{dx}$ which describes the oil-water tilt. The importance of the accuracy of either one cannot be overstressed.

A hydrostatic head of 1 psi corresponds to 2.2 feet of water. Consequently, if a bottom-hole static pressure is $\pm$ 5 psi, the maximum error possible between two wells is 10 psi, or 22 feet of water. Thus if $\pm$ 5 psi is to be the error involved, the wells will need to be at least a mile apart on a 22 foot/mile gradient in order to register the difference in bottom-hole pressures. In the case of a 10 foot/mile gradient, the wells in question would have to be approximately 2.2 miles apart.

Similarly, the effect of any inaccuracies in elevation can be demonstrated. The depth "z" can be measured accurately by means of tallies or wireline measurements. But "P" has

to be measured by means of more elaborate instruments. To let the hole fill with fluid is not practical and not always possible. The drill stem test is presently one of the best means of accurately establishing the value of "P".

Drill stem test. Probably the most common but least understood method of obtaining subsurface pressures is the drill stem test. For general consideration, drill stem testing may be divided into two main categories—open hole and hook-wall. The basis for this division is the condition of the hole at the time the drill stem test is taken.

The hook-wall method is applicable in cased holes. Operating and mechanical principles of the two strings of tools are the same. For this reason, only the open-hole string will be considered. The predominance of open-hole testing (approximately 75 percent of all testing is open-hole) definitely places it in the category of exploratory tools.

Trends in modern drill stem testing have led to more versatile and, consequently, more complex tools. The various components that go to make up a test string can be assembled in any number of combinations. Only the most important parts of the string will be considered (Figure 6).

Starting at the bottom of the string, the most common combination of testing tools and their main function is as follows:

The blanked-off pressure recorder (outside gage) provides a step-by-step graphic story of the drill stem test. By comparison with other gages in the string it will reveal the proper function of the testing string. No flow of fluids from the formation passes by this gage; consequently, all pressures are recorded directly from the annulus below the packer.

The perforated anchor supports the testing string and keeps the packer seated in the well-bore. The anchor also is provided with small holes (approximately 3/16-inch) to allow passage of the formation fluids and to screen debris that might otherwise plug the choke or fluid-passages in the tool.

The packer assembly provides a bridge in the well bore between the drilling fluid and the zone to be tested. The hydrostatic head is withheld from the formation after the tester valve is opened by means of the packer.

The flow stream gage (inside gage), like the blanked off pressure recorder, will give a concise picture of the testing operation. This pressure recorder is placed in the flow stream above the packer. All pressure fluctuations must pass through the perforated anchor in order to reach this recorder.

The tester valve prevents entry of drilling fluids into the empty drill pipe while running in the hole. It also retains a sample of the formation fluids recovered while pulling out of the hole. A number of improvements on the tester valve have been offered the industry in recent years.

Two of the most important features have been:

1. A delayed action opening controlled by a hydraulic system (this delayed opening gives the packer time to expand and obtain a partial seal before the tester valve is opened).

2. The combination bypass valve and tester valve, which prevents the possibility of having the tester valve open prior to the closing of the bypass valve. In this mechanical combination, either the bypass is open and the tester valve closed or vice versa.

The air chamber gage is optional but generally is run inside the air chamber on tests where an initial closed-in pressure is taken. This recorder provides a means of checking the air chamber for fluid entry prior to the opening of the tester valve.

The auxiliary valve is placed at a calculated distance above the tester valve to provide an air chamber into which compressed mud below the packer may flow when the packer is seated and the tester valve is opened. This method allows the pressure beneath the packer to drop below reservoir pressure. This will give the formation a chance to produce for a short time and will result in the recording of a static formation pressure prior to any appreciable amount of production.

Two types of auxiliary valves are available for the dual closed-in pressure procedure. One is the disc valve, which consists of a steel body with a fluid passage blanked-off by an aluminum disc. This type valve is opened by dropping a steel bar to rupture

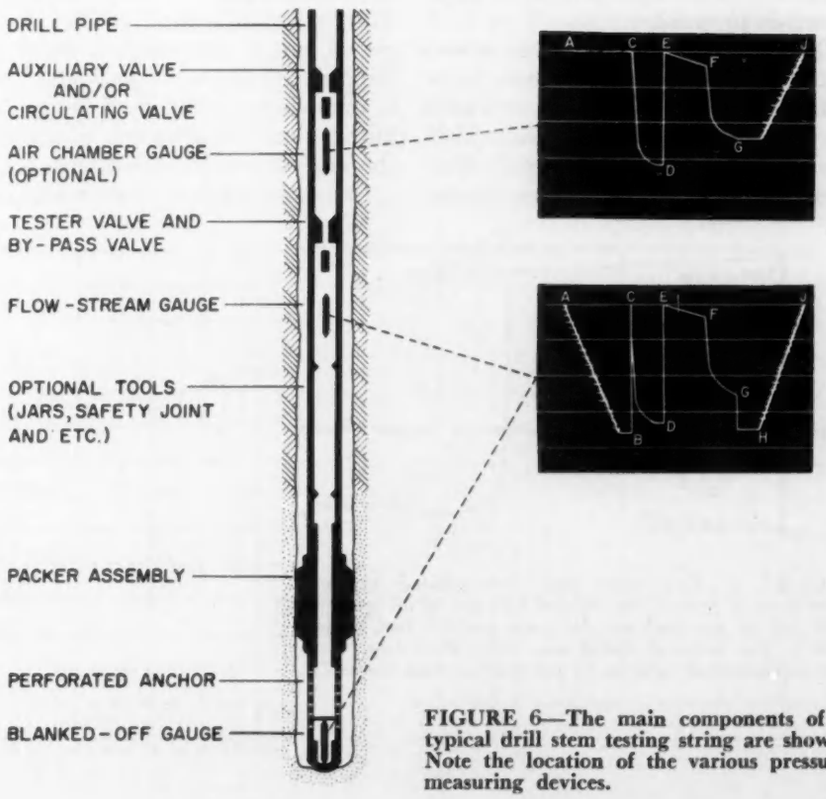


FIGURE 6—The main components of a typical drill stem testing string are shown. Note the location of the various pressure measuring devices.

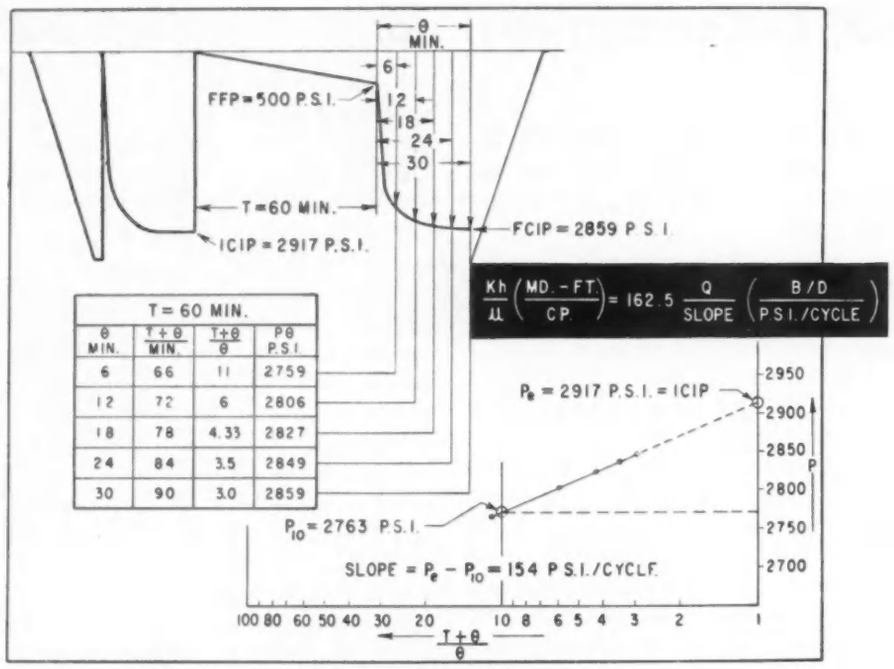


FIGURE 7—The method of extrapolating the correct aquifer pressure from a typical DST pressure chart is shown. The pressure P is plotted versus log $\frac{T+\theta}{\theta}$ where T is the time the tool was open to flow and θ the time the tool was closed-in during the FCIP period. The straight line obtained is extended to where $\frac{T+\theta}{\theta} = 1$. The pressure at this point is supposedly equal to reservoir pressure and should equal the ICIP. The formula shown can be used to calculate the permeability from information yielded by the test. (Note: Extrapolation curve for demonstration only—not to scale.)

the disc. Another valve is a rotation type which has a three-position sleeve. The valve is run in the closed position and is opened by right-hand rotation. Further rotation will again close the valve and provide a final closed-in pressure.

There soon will be available to the industry another rotation type auxiliary valve (which operates similarly to the valve described above). This newer type auxiliary valve will offer two advantages over present equipment. It will eliminate the necessity of the additional piece of equipment necessary to reverse out the recovery obtained on the drill stem test, and the air-chamber and the calculations for obtaining it will be eliminated. This valve is opened to flow for a period just long enough to bleed off the pressure below the packer. It then is immediately shut-in to record the initial closed-in pressure eliminating the necessity of the air-chamber.

Important optional components of a testing string are safety joint, jars, bottom-hole choke, reversing sub, etc. (Local conditions will govern location of the tools in the string and their application).

With the advent of drill stem testing, little thought was given to pressure recorders. The drill stem test was run with only three objectives in mind: would the formation produce, how fast would it produce and what would it produce.

Later, it was felt that some tests were concluded to be "dry" or nonproductive, when actually there was a test tool malfunction. To overcome such erroneous conclusions, it was decided to develop some type of subsurface recording device which would indicate behavior of the tools.

The first gages were very inaccurate (as far as pressures were concerned) but adequate for their purpose. The results of this procedure were so desirable that many other advantages were immediately brought to light. Presently, gages are both accurate (within reasonable limits) and reliable.

Table 1 shows the approximate relationship between cart deflection and pressure. A reading error for example, on an 8,000 psi gage will be twice that of a 4,000 psi gage. To minimize

TABLE 1—The relationship between chart deflection and pressure.

Range of Gage	Pressure (PSI)/ .001" Deflection
2,000 PSI	0.50 PSI
3,000 PSI	0.75 PSI
4,000 PSI	1.00 PSI
5,000 PSI	1.25 PSI
6,000 PSI	1.50 PSI
8,000 PSI	2.00 PSI
10,000 PSI	2.50 PSI
12,000 PSI	3.00 PSI
15,000 PSI	3.75 PSI
20,000 PSI	5.00 PSI

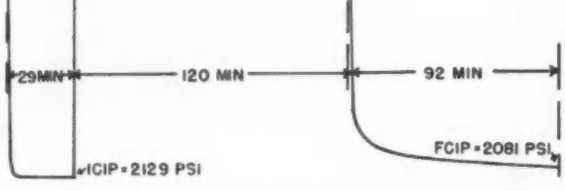
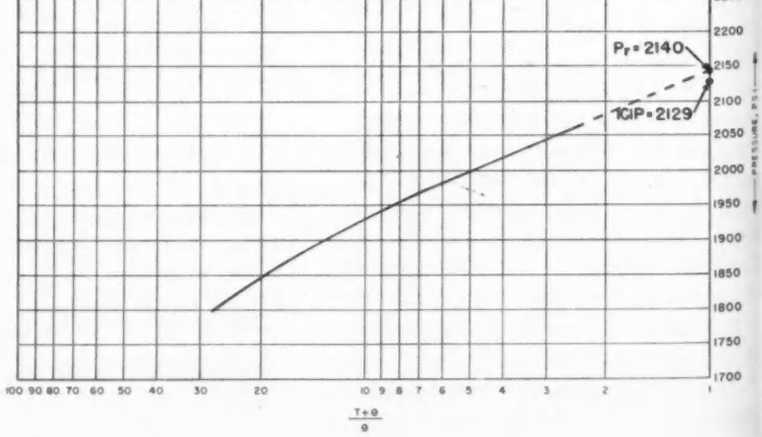


FIGURE 8—This chart and extrapolated pressure were from a well which yielded 220 feet of oil and gas, 120 feet of gas and oil cut mud and 80 feet of salt water. The interval tested was 4429-4454 feet. Note the extrapolated value is 11 psi greater than the ICIP.



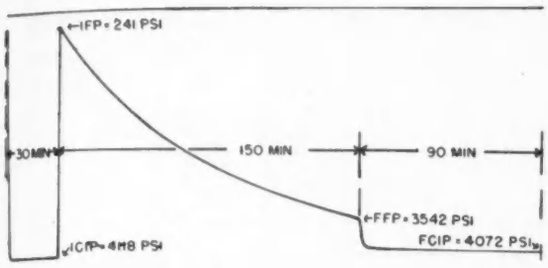
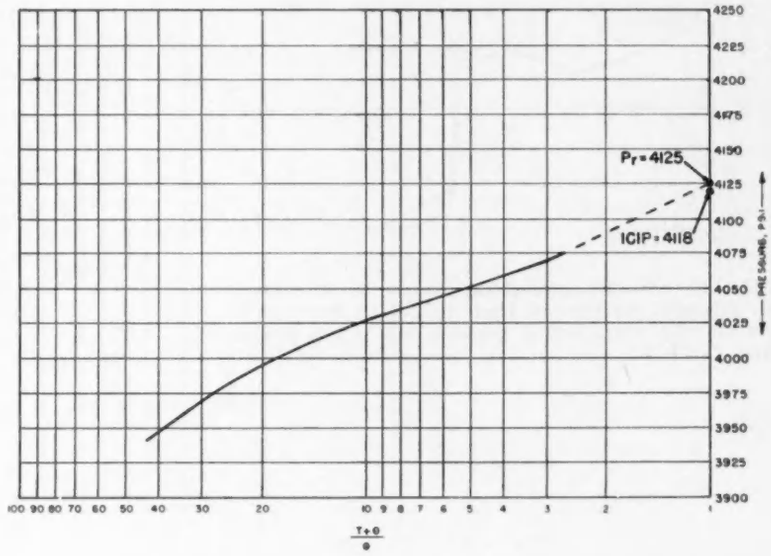


FIGURE 9—This test resulted in recovery of 7020 feet of muddy water from 8611-8674 feet. The extrapolated reservoir pressure was 7 psi greater than the ICIP.



reading error, it is advisable to use the lowest pressure-range gage possible.

A second component of the recorder is the clock. Although time is independent of pressure recordings, it is important for interpretation of results. Proper selection of clock speed will tend to minimize errors resulting from interpretation of the chart. Clock speeds are available to the industry in 12-, 24-, 48-, and 72-hour ranges.

Drill stem tests usually should be run with at least two pressure recorders. The application of two recorders is the only method by which an accurate analysis of tool behavior can be made. One recorder should be below the packer in the blanked-off position recording annulus pressure. The second recorder should be in the flowstream above the packer but below any bottom-hole choke used. To correctly and safely analyze a drill stem test, it is essential that two recorders be employed in the manner described. In this way, plugged perforations, chokes etc. may be detected.

The metal charts on which pressure and time fluctuations are recorded are especially coated to withstand the high bottom-hole temperatures encountered in deep testing. A base-line (zero pressure line) is drawn on the chart after the instrument has been assembled. Recordings made during a test are measured in inches of deflection from the base-line and converted to pressures by means of a calibration curve.

These calibration curves are individually drawn for each recorder in temperature ranges from 100° to 350° F. Pressure readings from the charts are corrected to bottom-hole temperature to meet the specific conditions under which the test is made. Temperature readings used in the correction procedure are obtained either by the use of a maximum thermom-

TABLE 2—A summary of statistical data on extrapolated pressure errors with suggestions for improvement.

Portion of Recorded Chart Available for Extrapolation	Present Error In Extrapolation (Average)	Suggestions Towards Improvement of Extrapolation	By Application of Suggestions, Error May be Reduced to
Inital Closed-in Pressure Curve	34 psi	Extend time to a minimum of 60 minutes	25 psi
Flow Period Curve Plus Final Closed-In Pressure Curve (Conventional Test)	±31 psi	Extend Closed-in Period to 1—2 times Flow Period	±13 psi
Initial Closed-In Pressure Curve Plus Flow Period Curve Plus Final Closed-In Pressure Curve (Dual CIP Test)	±18 psi	Extend ICIP time a minimum of 60 minutes and Extend Final Closed-In Period to 1—2 Times Flow Period	± 6 psi

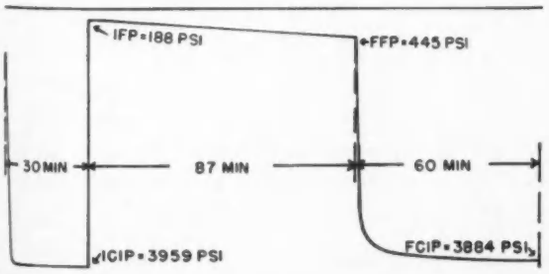
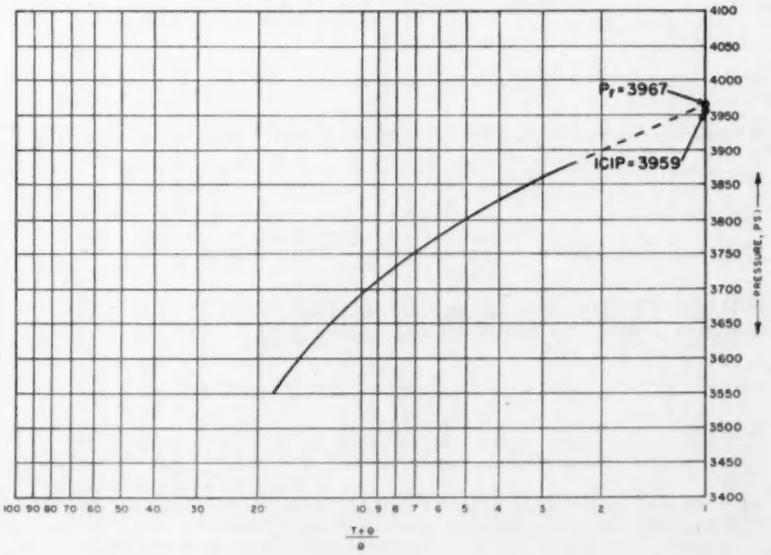


FIGURE 10—This test recovered 222 feet of mud cut water and 630 feet of water from 8364-8400 feet. The extrapolated pressure was 8 psi more than the ICIP.



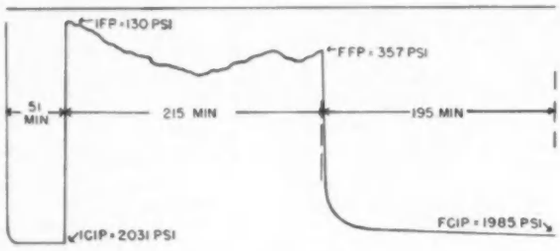
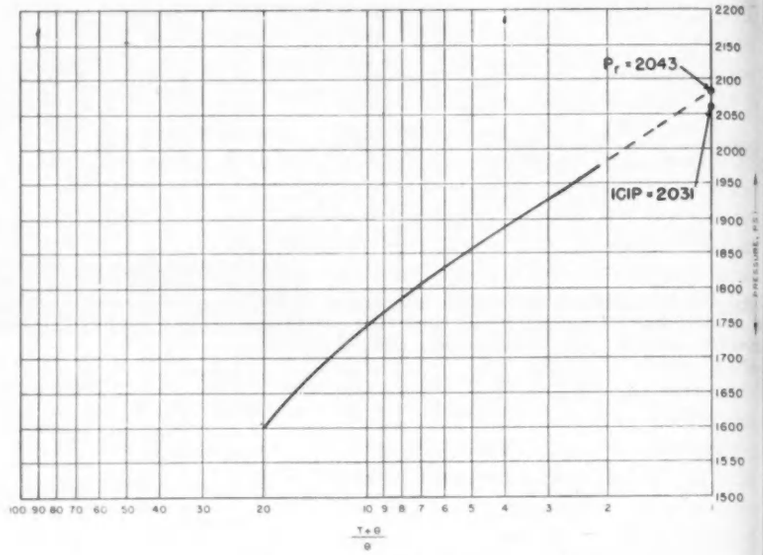


FIGURE 11—Oil reached the surface in 92 minutes on this test. An interval from 4692-4714 feet was invested. The extrapolated pressure was again greater than the ICIP.



eter run as a component part of the testing string or by applying the geothermal gradient of the area in which the test was run. In wildcat areas where the geothermal gradient is not well established, it is particularly advisable to run a temperature device. This information may also be used for electric log interpretation and fluid density corrections.

Pressure evaluation. The theory of pressure build-up interpretation and extrapolation has been well covered in the literature.[2,7,8,9] Formulas of major interest are shown in Figure 7. This figure shows a straight line extrapolation through points obtained by plotting the pressure P versus $\log_{10} \frac{T+\theta}{\theta}$ in which T is the time the tool was open to flow and θ the time the tool was closed in during the final closed-in pressure (FCIP) period. The straight line thus obtained is extended to intersect the line for which $\frac{T+\theta}{\theta} = 1$. The pressure at this point of intersection supposedly is equal to the aquifer pressure. Thus the value should be the same as that of the measured initial-closed-in-pressure (ICIP).

The slope of the straight line obtained in the above manner can be used to calculate the permeability of the formation and to estimate effects of well-bore damage. These calculations and estimations are beyond the scope of this paper, and are mentioned for re.erence only.[2,7,8,9,10]

Theoretically, a straight line will be obtained through the points as indicated in Figure 7. In practice, however, this line is frequently curved. For comparison, 162 drill stem tests taken at random throughout the Williston Basin were evaluated. Figures 8 through 13 are representative of drill stem test charts in the Williston Basin and are shown with their extrapolation on semilogarithmic paper. It can be noted that such extrapolation does not need to be a straight line. No apparent correlation exists between the degree and direction of curvature and the quantity and type of production obtained. In the following paragraphs, it will be shown what effect this curvature may have upon the accuracy of the extrapolated aquifer pressure and how such accuracy may be improved by proper timing of the drill stem test intervals.

TABLE 3—Variation of the values of an ICIP with relation to time. This data was obtained with the use of an oversize air chamber and indicates the importance of longer ICIP periods.

Point	C.I.P. Time θ	Pressure Reading
1	15 minutes	1859
2	30 minutes	2056
3	45 minutes	2091
4	60 minutes	2106
5	75 minutes	2115

Development of ICIP Curve

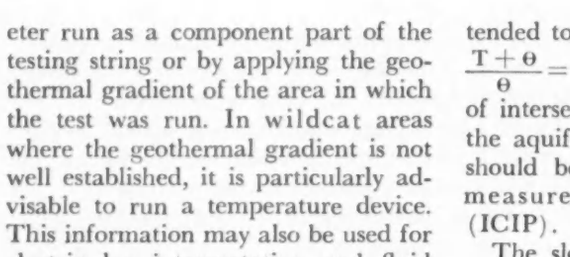
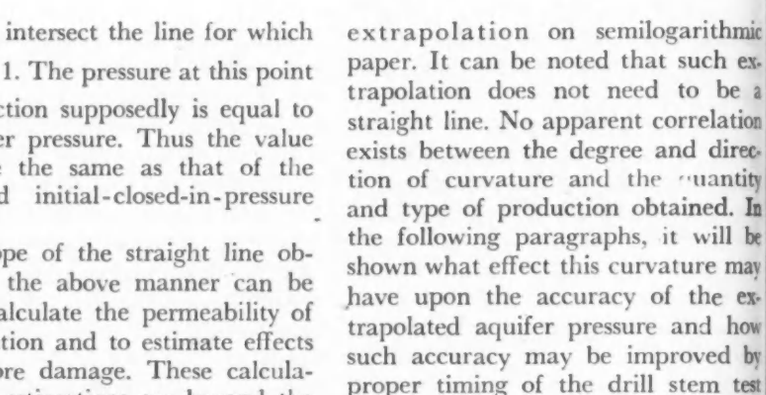


FIGURE 12—This test of an interval from 4447-4465 feet yielded 160 feet of oil and gas cut mud.



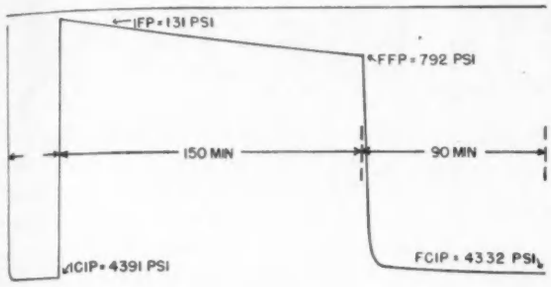
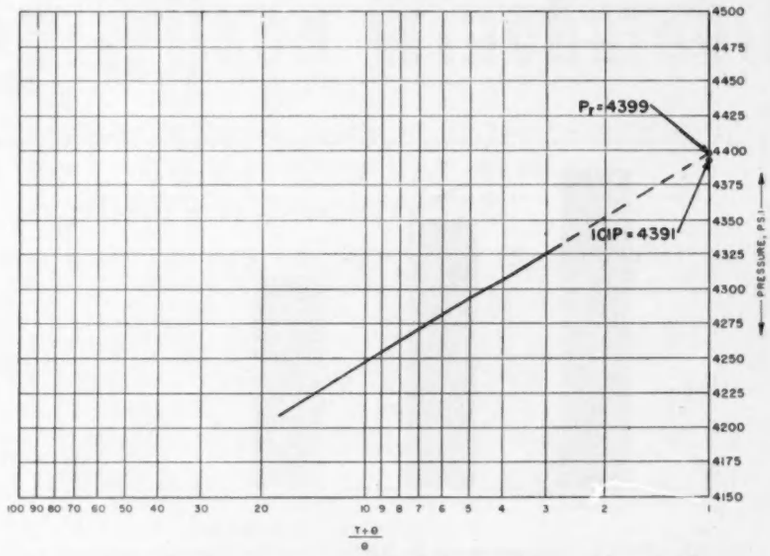


FIGURE 13—This interval, 9172-9223 feet, yielded 210 feet of mud and 1590 feet of gas cut salt water. Note the almost straight line pressure plot resulting from this test.



To further illustrate the competence of aquifer pressures obtained from extrapolated DST pressure data, reference is made to Figures 14 and 15. Figure 14 shows the possibilities of development of the FCIP curve if the tool has been left shut-in for 10, 15, 30, 60 or 120 minutes during such period. A considerable difference in the curves can be visualized in the different instances. Figure 15 shows the extrapolated FCIP curves for the corresponding shut-in periods as illustrated in Figure 14.

Thus, it can be seen that the difference between the maximum and minimum extrapolated value for the reservoir pressure decreases considerably with longer shut-in times.

By the same token, the ICIP helps to decrease the difference between maximum and minimum extrapolated values since the minimum is not likely to be less than the ICIP value.

The practice of taking an ICIP is highly recommended. The time necessary to obtain a good ICIP depends

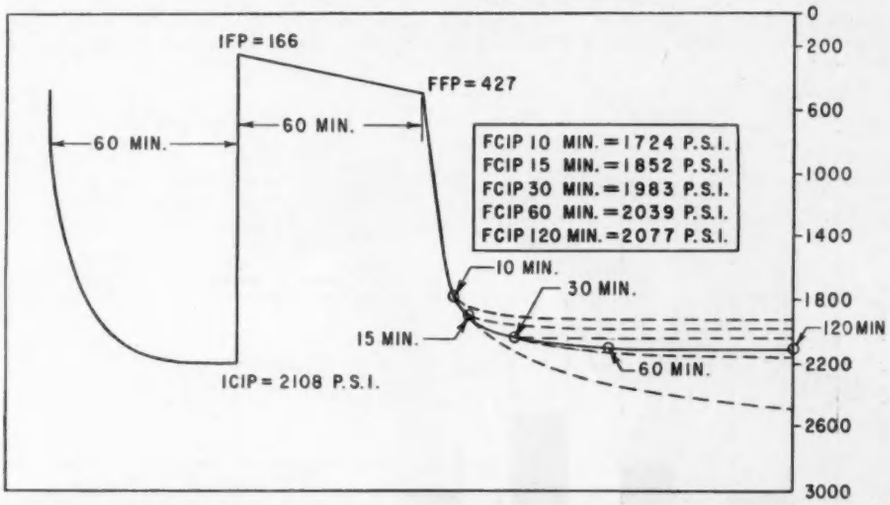


FIGURE 14—This dual closed-in pressure chart indicates the possible development of the final closed-in pressure curve for different shut-in times. It is apparent that varying interpreted results can be obtained from different shut-in times.

TABLE 4—The frequency of initial closed-in pressure times used in Williston Basin.

I.C.I.P. Time, Minutes	Frequency N	*Percent for Each ICIP Time
15 to 30	72	64.9
30 to 45	27	24.3
45 to 70	12	10.8

(* Percentage based on 111 Dual C.I.P. tests studied)

TABLE 5—Frequency of various ratios of the final closed-in pressure to the flow period in the Williston Basin.

Closed-in Period — θ / Flow Period — T	Frequency N	*Percent for Each θ/T Ratio
1/6 to 1/4	35	21.6%
1/4 to 1/3	16	9.8%
1/3 to 1/2	23	14.2%
1/2 to 1	33	51.3%
1 to 2	5	3.1%

(* Percentage based on 162 tests studied)

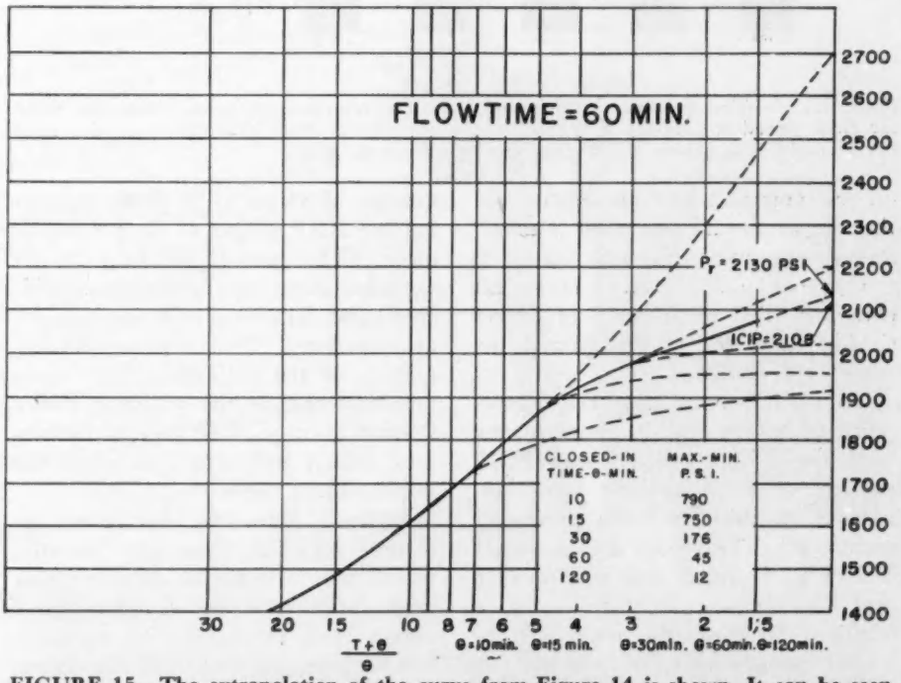


FIGURE 15—The extrapolation of the curve from Figure 14 is shown. It can be seen that the difference between maximum and minimum extrapolated reservoir pressure values decreases considerably with longer shut-in times.

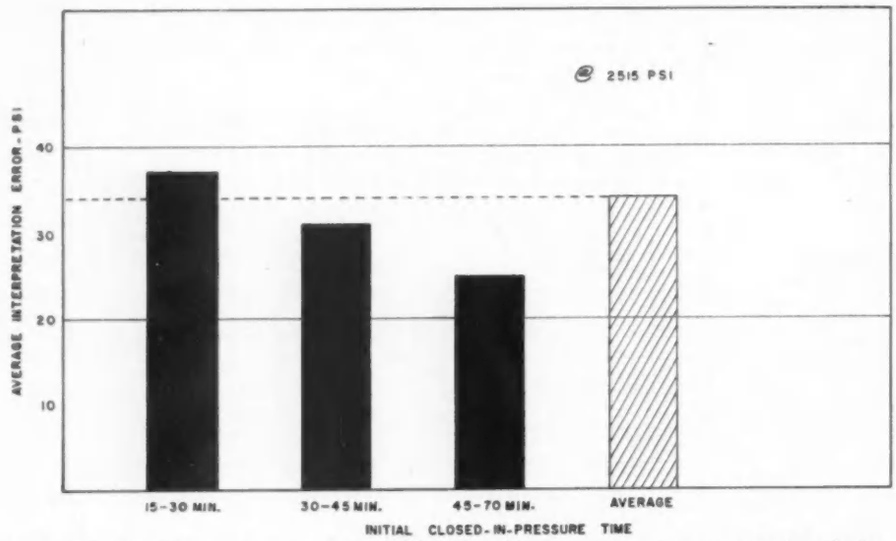


FIGURE 16—The average error in initial closed-in pressure measurements in relation to shut-in time is illustrated. This average is for wells in the Williston basin. The present average error could be improved by extending the ICIP period to 60 minutes or more.

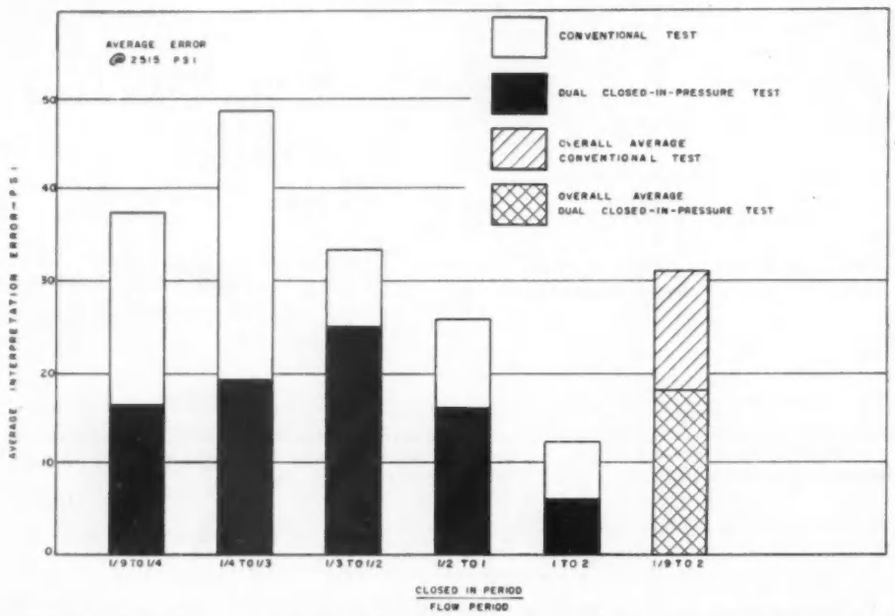


FIGURE 17—The average extrapolation error for reservoir pressures versus the ratio for final closed-in pressure time/flowtime is illustrated. Note that the error decreases considerably with longer ICIP times and by taking an ICIP.

on reservoir and hole conditions and the size of the air chamber. Table 3 shows pressure versus time values in the case of a somewhat large air chamber. The importance of longer shut-in time during this period becomes self evident.

To further emphasize the importance of longer shut-in times during both the ICIP period and FCIP period, statistical analyses were performed on the 162 tests previously mentioned. The results are shown in Tables 2, 4 and 5 and Figures 16 and 17.

Figure 16 shows the error in ICIP measurement versus the time the tool was left shut-in during this period. This error can be improved from a present average of 34 psi to 25 psi by extending the ICIP period to 60 minutes or more. (The present value of 34 psi excludes those measurements considered total failures due to precharged air chambers.) Table 4 shows the frequency of the different ICIP times presently used in the Williston Basin. Present average ICIP time is 35 minutes, which indicates that room for improvement exists.

Figure 17 shows the average extrapolation errors for reservoir pressure versus the ratio for FCIP time/flow time. Tests with or without ICIP curves were considered in the analyses. It can be seen that the extrapolation error decreases considerably with longer FCIP times and by taking an ICIP. The present average error of ±31 psi for a conventional test (no ICIP) can be reduced to ±18 psi by taking an ICIP. The error can be further reduced to ±6 psi by leaving the tool closed-in longer. Table 5 depicts the frequency of FCIP time/flow time ratios presently used in the Williston Basin.

The present practice is to leave the FCIP time approximately one-half the flow time. There is again considerable room for improvement in this respect.

Table 2 summarizes the statistical data on the errors as presently occurring and what can be done to improve extrapolation accuracy.

Conclusion. It has been pointed out that the most sensitive data necessary for hydrodynamic study is the pressure of the fluid in the aquifer. Presently, the drill stem test possibly is the best tool available to obtain these pressures, especially where such tests are taken before any fluid has been withdrawn from the aquifer.

A total of 162 tests, taken at random throughout the Williston Basin, were studied for this presentation. An analysis was made of the errors which may result from both the measurement and the extrapolation method applied. The errors shown do not include any inherent inaccuracies of the measuring instruments used to obtain the pressures. However, it should be pointed out that whatever such instrument errors may be, final error may be reduced by application of more than one gage on each test.

If accurate pressures are desired (as for hydrodynamic purposes) it has been statistically pointed out that:

- An initial closed-in pressure is beneficial.
- With the present practice of initial closed-in pressure measurements involving the air chamber, the closed-in time during this period should be at least 60 minutes.
- The ratio of the final closed-in pressure time/flow time needs to be increased to approximately 1.5. Particularly in the case of low production intervals, the tool should be left shut-in for as long a period as possible.

ACKNOWLEDGMENT

The authors express their appreciation to the Halliburton Oil Well Cementing Company for permission to present and publish this paper; and to H. G. Lovett of Halliburton, who assisted in the extrapolation of the charts which were used in the statistical analyses.

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[2] Horner, D. R. "Pressure Build-Up in Wells."

Continued on Page 104

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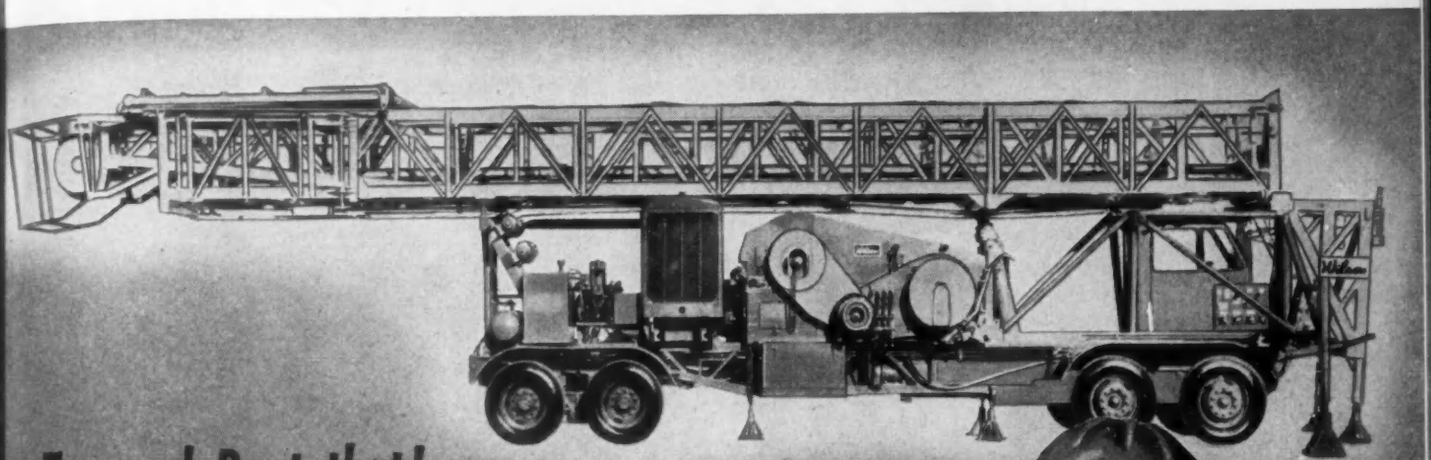

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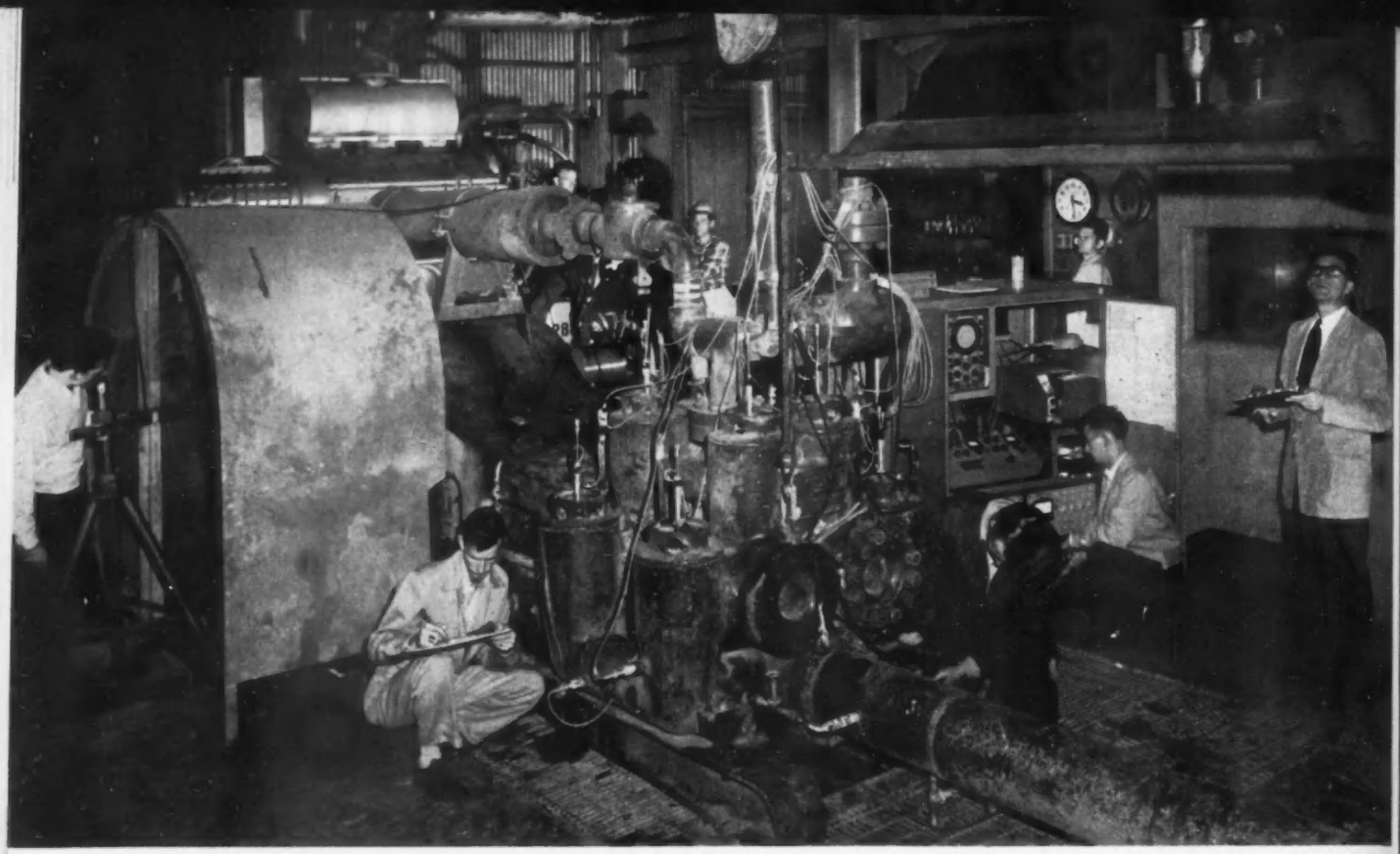


FIGURE 1—An oil field mud pump rigged up in the laboratory for complete stress and strain analysis under operating conditions.

PART 1: INTRODUCTION

Know your mud pump—it can save you money

Data based on extensive research into pump operation reveal cost saving methods of mud pump operation

By Samuel L. Collier
Mission Manufacturing Company, Houston

DRILLING COSTS can be reduced through a better understanding of the mud pump and accessory equipment. The preliminary results of carefully controlled laboratory tests made with the most modern instrumentation will aid in acquiring a better knowledge of pump operation.

Figure 1 shows a typical setup of oscillograph and mud pump used to collect the backgound material for this work. Nearly 4,000 oscillograph records were made under various conditions of operation. The program is being continued. The conclusions, now possible, will be presented in this series of articles together with pointers for applying this information in the field.

The mud pump is the main element of the surface mud system, but it is only a link in the three element chain consisting of the suction system, the mud pump itself and the discharge system.

The actual requirements of the suction system must be understood in order to establish the correct operating conditions for the mud at the pump suction flange. To know what is required of the suction system, both the normal and abnormal situations that occur during, and as a result of, the suction stroke of the piston must be understood.

In the discharge stroke, the piston's pattern of motion is molded into a completely different pattern by the complexity of the discharge system. Each element of the system should be operated for the maximum effectiveness by controlling the problems of each through the best use of the piping and the mud reserve, or when necessary, the proper use of the auxiliary equipment.

The mud pump operation. It is a mistake to belive that the operation of a power pump is so simple that

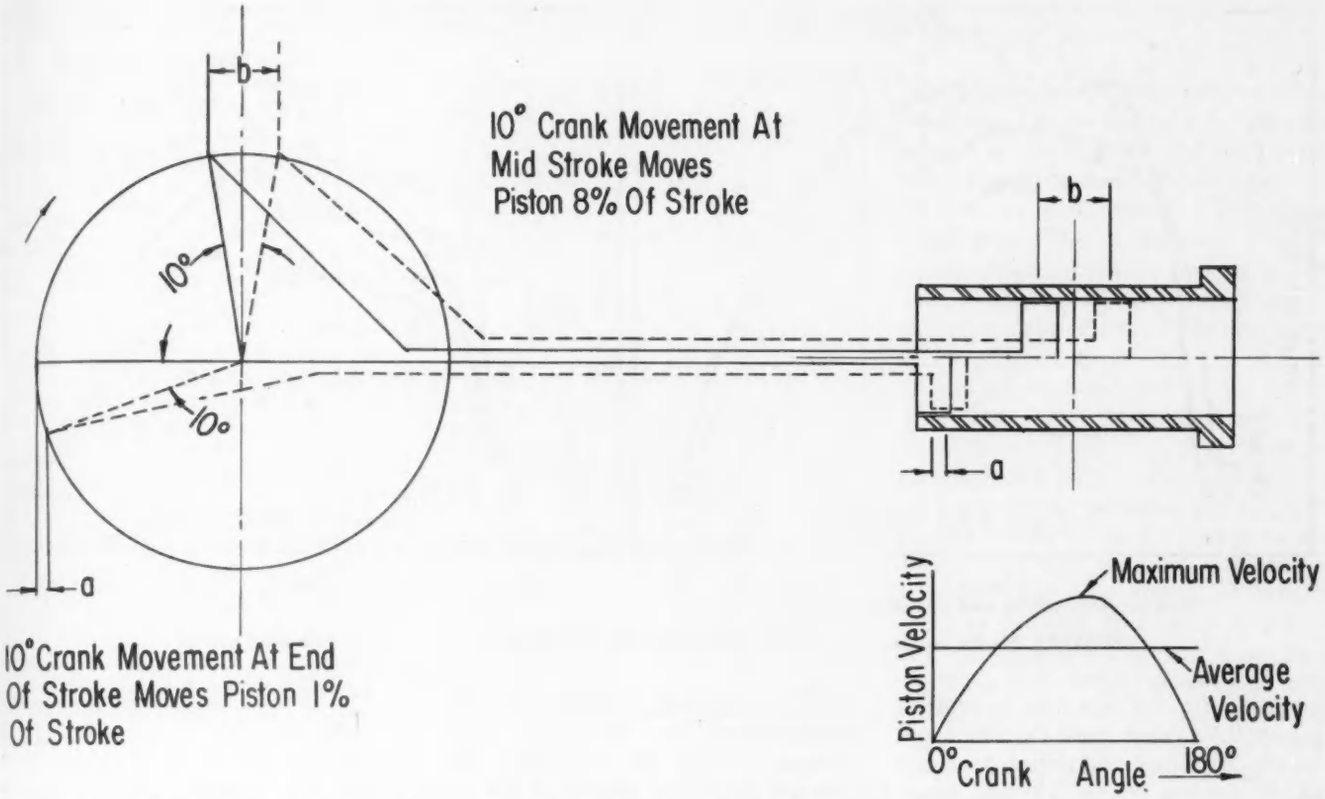


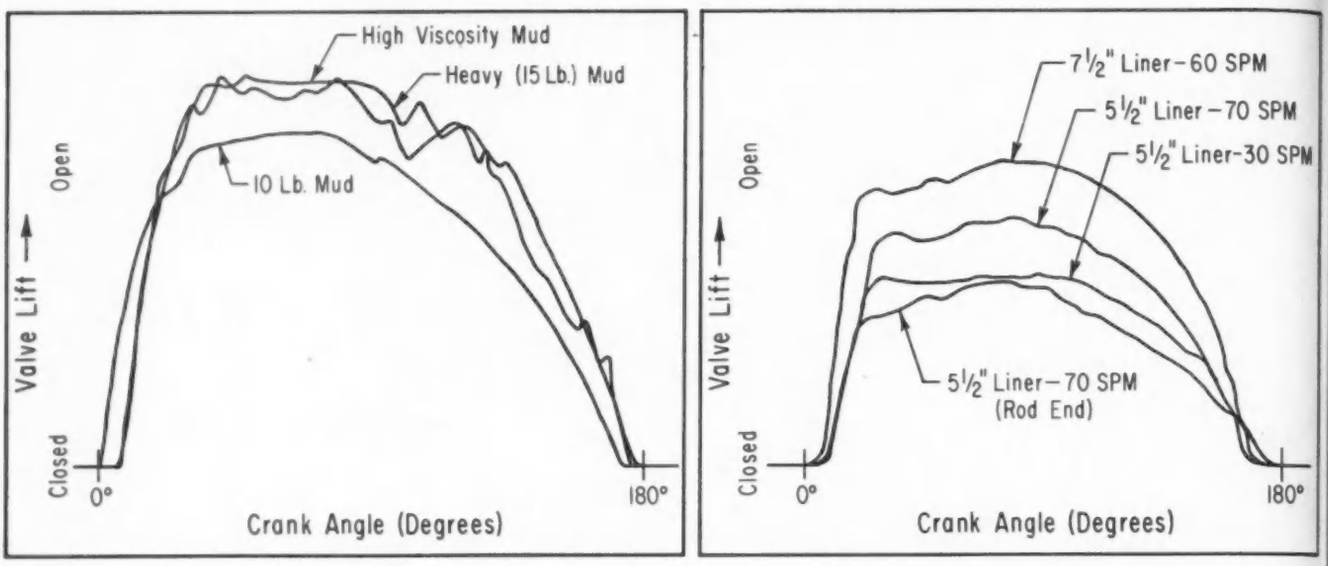
FIGURE 2—A schematic drawing of mud crank and rod linkage showing how rotary motion is transferred into reciprocating motion.

it is not necessary to understand it. Knowledge of its operation is the key to the understanding needed. The most basic factor in understanding the power pumps operation is the variation or pattern of the piston's motion. This motion, which approximates simple harmonic motion, is the result of the transfer of the rotary motion of the crank to the reciprocating motion of the piston. At the end of the stroke, the crank must turn through a great many degrees to cause a slight motion of the piston; and since the crank moves at a constant speed, the piston speed is low. The speed increases until in the middle of the stroke the crank moves only a few degrees to cause a large movement of the piston and the piston speed is the highest. Referring to Figure 2 we see that for a 14 inch stroke pump, 10 degree motion of the crank from the end of the stroke results in a movement of the piston of less than 1 percent of the stroke or 1/10 inch. However, in the center of the stroke a 10 degree movement of the crank results in a movement of over an inch of the piston, or 8 percent of the stroke. Three things are noticed from the above; (1) the piston speed or velocity is variable throughout the stroke; (2) the velocity of the piston although variable depends on the rotation of the crank or strokes per minute, and (3) the piston speed varies; it accelerates or decelerates. The things that make a power pump different from a steam pump are; (1) the variation of velocity during a stroke at a given speed, (2) the rate of velocity variation. These are of fundamental importance in understanding the behavior of both the suction system and the discharge system.

Normal operation. An examination of the behavior of the pump, and its function during normal operation will enable the driller to better cope with the difficulties of abnormal operation. Tests made during standard operation of a mud pump, without any auxiliary devices, shows that many of the various factors in which we are interested behaved so as to produce a regular predictable pattern.

The liquid mud entering the pump at the suction flange is relatively cool and contains a negligible amount of entrained air or gas. The mud in the suction manifold does not move until the suction valve opens. As the piston moves from its end position a slight pressure reduction occurs which lifts the suction valve open. The valve opens rapidly about as fast as the shutter tripping on a box camera, but its action is smooth.

Figure 3 is an oscillograph record of a valve operating in a 5½inch x 14 inch duplex mud pump. Figure 3a is typical normal valve behavior for the case in which 10-pound mud is being handled and also when heavier mud or viscose mud is being handled. Normal curves, for the 7½ inch liner size showing a somewhat higher lift, (Figure 3b) are included to show the various normal curves that the valve motion may have. Notice that after the first brief opening period, the valve lift pattern takes a curvature very similar to that of the piston velocity curve shown in Figure 2. Valves are not designed to be flow measuring devices but the valve lift is actually proportional to the piston speed—high lift at mid stroke and low lift at low piston speed. The valve position indicates the amount of mud flowing through the valve at that instant. This is significant because it shows that the maximum rate of flow through the valve, the pump and the suction line must be much higher than the average flow in order to make up for the low rate of flow at each end of the stroke. In fact, for the simplest case, the maximum flow is about 156 per-



3a.
Effect of mud weight and viscosity change.

3b.
Effect of pump speed.

FIGURE 3—An oscillograph record of normal valve operation of a 5½ by 14-inch mud pump.

cent of the average for a simplex pump. This point must be considered in the frictional and other problems of the suction piping. The test measurements also show the gentle way in which the valve closes, which is a result of the piston slowing down and stopping at the end of the stroke.

Throughout the stroke the valve merely reflects the action of the piston; rising to show increase and falling to show decreases in piston speed. Thus, the valve is dependent on the piston for its behavior pattern. At the end of the stroke the piston reverses its direction. In a few degrees of crank rotation the piston moves enough to close the suction vale, compress any minute gas or air particles, compress the mud trapped in the lines and clearance space, and to swell the liner and fluid end as it moves forward at a very low speed. Since mud is difficult to compress, the pressure rises rapidly finally reaching a pressure great enough to force the discharge valve open and to pump the mud into the discharge line.

The rate is not steady. At first, piston speed is low, but toward midstroke the speed rises as it did on the suction stroke causing a continuous increase in the rate of discharge and in the lift of the discharge valve. After midstroke the piston begins to slow down and the discharge valve follows the pattern by closing in proportional amounts.

Since the discharge system has fixed dimensions, the pressure rises during the period at midstroke when the discharge flow rate is far above average to push the additional fluid through the water course at the bit. This results in a line pressure proportional to the rate of flow and piston speed. The pressure is low at the beginning of the stroke and high in the middle of the stroke.

The actual test shows that valves behave with the same pattern for simplex and duplex pumps, both single and double acting, but the pressure patterns differ. The pressure curve in a simple pump follows the calculated curve very closely. These curves may be superimposed on each other for duplex pumps with the re-

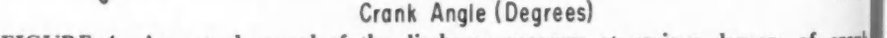


FIGURE 4—An actual record of the discharge pressure at various degrees of crank rotation. The pressure is directly proportional to the flow rate and the piston speed.

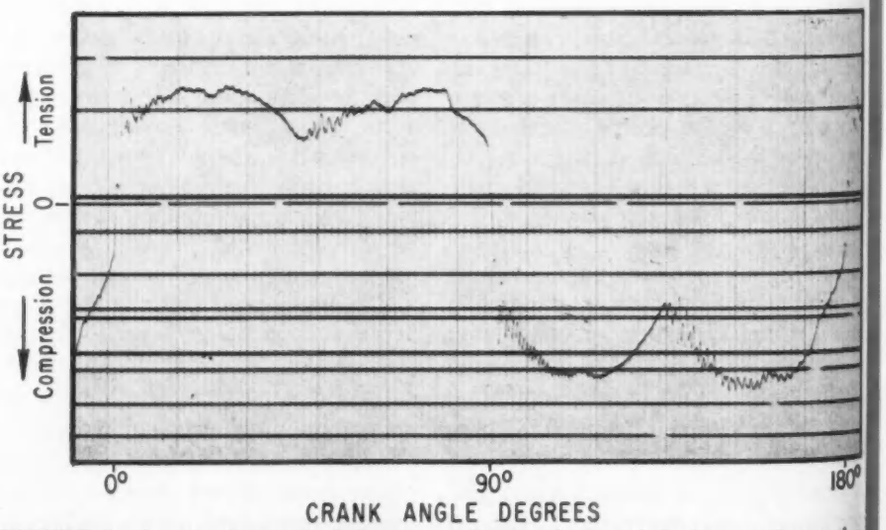


FIGURE 5—An actual record of the stresses in the piston rod during crank rotation. This curve is a reflection of the cylinder pressure.

Normal Pump Behavior Must Be Understood . . .

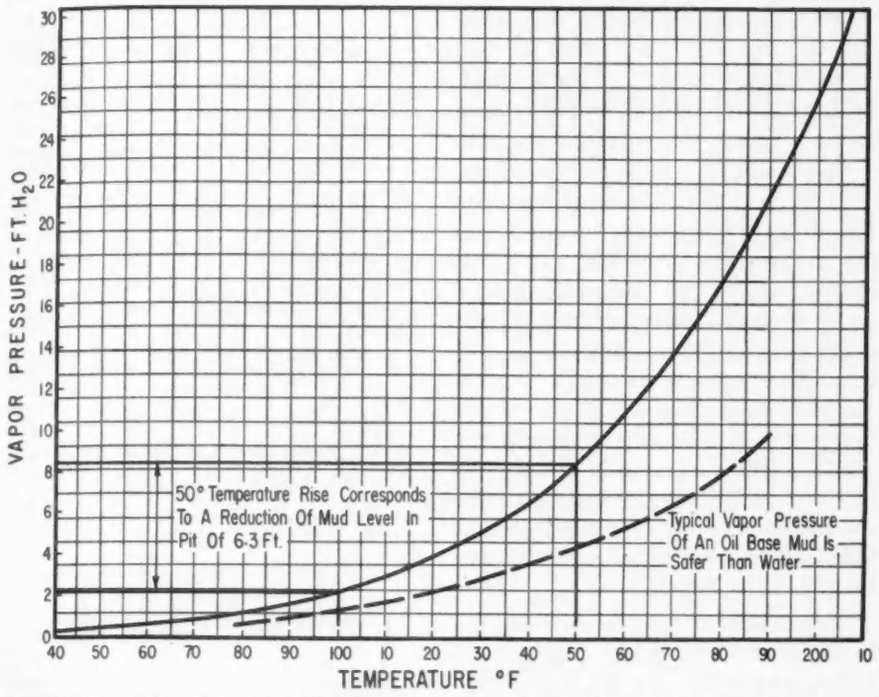

VAPOR PRESSURE-FT. H_2O
TEMPERATURE °F
50° Temperature Rise Corresponds To A Reduction Of Mud Level In Pit Of 6-3 Ft.
Typical Vapor Pressure Of An Oil Base Mud Is Safer Than Water

FIGURE 6—The effect of mud temperature on pump performance. Vapor pressure of water rises rapidly at temperatures over 100° F. resulting in a reduction of the section head.

sults shown by an actual test record in Figure 4.

The force of the fluid on the piston causes a stress in the piston rod. The average tensile or compressive stress in the rod is a reflection of the cylinder pressure. Laboratory tests confirm this for the case of a simple pressure curve or for the more complex pressure curve production by duplex pumps as shown by the test record for a rod in Figure 5. This is also true if the pressure pattern is changed in great degree as it may be by the use of dampeners in the discharge line or by the development of unusual pulsating conditions.

Abnormal behavior. A clear picture of normal behavior is needed to understand, evalute and correct unusual conditions or to improve on the operation of the mud pumps. If the mud temperature is high and the pump is driven at high speeds, poor filling will occur. The temperature effect is greater than would be supposed. The vapor pressure of water rises rapidly at temperatures over 100°F. From the curve, Figure 6, an increase in mud temperature from 100°F. to 150°F. raises the vapor pressure 6 feet. This has the same effect on operation as a drop of 6 feet in the mud level in the pit. If the pressure at any point in the system drops to vapor pressure, the liquid will boil and a void will develop. The mud should be kept as cool as possible and under bad conditions special equipment may have to be added. When there is no void in the system, system behavior can be studied using the principle of continuity, but the development of a void results in loss of continuity, thus making the problem much more complex.

The details of the problem of loss of continuity can be shown by studying a record, Figure 7, of the suction valve behavior taken under adverse operating conditions. Notice that the abnormal period is near the middle of the stroke. It can be deduced that a part of this condition causes an

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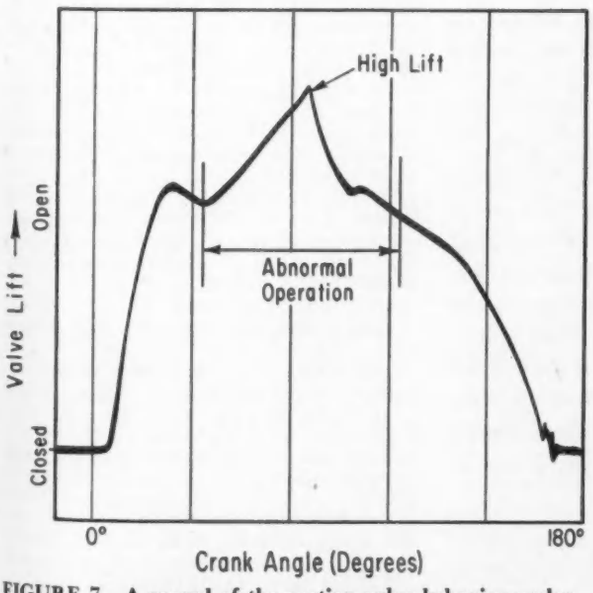

FIGURE 7—A record of the suction valve behavior under abnormal operating conditions.

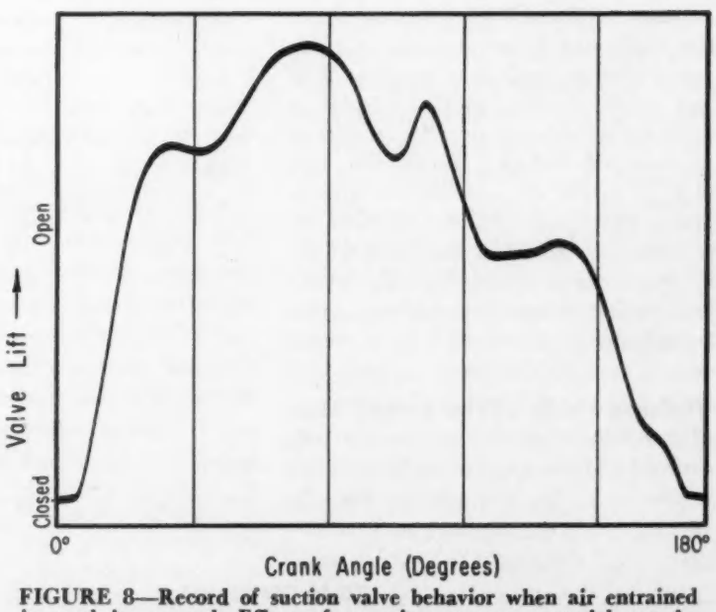

FIGURE 8—Record of suction valve behavior when air entrained in mud is pumped. Effect of pumping gaseous material can be predicted.

increase in flow velocity into the pump which is followed by a marked drop in velocity. Since the valve is a crude flow meter, the valve lift was much greater than usual. The curve also shows that the opening and closing characteristics of the valve are basically unchanged. If sufficient lift is not available, the valve would strike the upper guide.

It is possible to prevent the occurrence of a void by analyzing the factors to determine an acceptable suction piping design or to ascertain the need for, or benefit to be gained, from, use of the auxiliary suction equipment such as dampeners or prechargers. This analysis will be covered in detail in the series when the correct suction layout will be studied and its benefit in terms of longer parts life and greater efficiency at lower cost will be determined. Another abnormal behavior which is less evident, but important, includes the problems of handling aerated mud. Valve behavior is very erratic when aeration occurs or gas cut mud is handled.

Figure 8 is a recording of the suction valve behavior when air has been carried through with the mud. The normal predictable behavior is largely destroyed, but greater than normal opening occurs and larger pump lift is necessary to prevent striking the upper guide. Handling gaseous material has a definite predictable effect on pump efficiency.

The development of a void or passing of gaseous material does not create such erratic behavior in discharge valves. Since these valves are surrounded by a high pressure fluid, the voids are filled and gas is compressed to a negligible portion. Any gas taken in the suction stroke is reduced to about 1 percent or less of its original volume. Since the discharge valves do not behave abnormally, the erratic valve will have to be a suction valve in the suction pot. If the noise is there, the real problem, which is aeration, or voids, can be attached.

Discharge side of the pump. Most of the factors considered on the suction side of the pump involve smooth operation. The key factor on the discharge side, is service life which is influenced by pressure and its fluctuations, resulting in corrosion fatigue of the parts. It is harder to define normal and abnormal than it was on the suction side. Here the hydraulic horsepower output and length of service life are the points of interest.

The hydraulic horsepower output of the pump depends on the suction conditions which will determine if the pump cylinder is full for a discharge stroke and also will depend on the system pumped into. If the cylinder is not completely full, a portion of the power stroke is wasted, and the volumetric efficiency of the pump is low. This condition will also result in a development of abnormally high stresses in the piston rod since the piston will have gained considerable speed before it contracts the mud in an unfilled cylinder.

These points will be investigated in detail to help select pump parts and discharge equipment in order to get the longest life and the most hydraulic efficiency.

The next article will present methods to calculate the limitations of a given system and the effects of changes on a given system such as changes in diameter and length of suction pipe. This discussion will concern the simplest approach to maintain high efficiency and smooth operation under adverse construction arrangements, or at high operating speeds that may be necessary to get the most from the pumps. In addition, problems such as poor but fixed arrangements between mud tank and pump can be corrected by the use of auxiliary equipment such as suction dampener or a supercharger. An efficient dampener can be built in the field if a few simple concepts are followed. Suprisingly the dampener can also be useful in correcting aeration problems. The supercharging pump is extremely useful under adverse conditions. Both devices make operation possible with poorly constructed suction systems if necessary. By using them in conjunction with good systems we can raise pump speed or handle gas cut mud and at an increase in efficiency.

TO BE CONTINUED

DST in Hydrodynamic Studies

Continued from Page 98

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About the Authors

van Poollen

Bateman

Dr. H. K. van Poollen is a citizen of The Netherlands. He received his bachelor of science degree in mining engineering at the University of Delft in Holland in 1948 and received his master of science degree in mining engineering at the Colorado School of Mines in 1950. He was in the Dutch Army in Holland from 1950 to 1951. After that, he joined Standard-Vacuum Oil Company in Sumatra, where he worked as a reservoir engineer until 1954. He returned to the Colorado School of Mines and received his doctorate in 1955 at which time he joined Halliburton Oil Well Cementing Company. He now is section leader of the reservoir engineering section of the Chemical Laboratories, Halliburton Oil Well Cementing Company, Duncan, Okla.

Sam J. Bateman, after graduation from Houston public schools, entered Texas A. & M. College, but his studies were interrupted by military service during World War II. He was graduated from the University of Houston in June, 1950 with a bachelor of science degree in geology and engineering and then was employed by Halliburton Oil Well Cementing Company. After field experience in Kansas and the Texas Gulf Coast, he became district engineer at Beaumont, Tex. In April, 1957, he was transferred to Duncan, Okla., as a development engineer in Halliburton's Testing department.

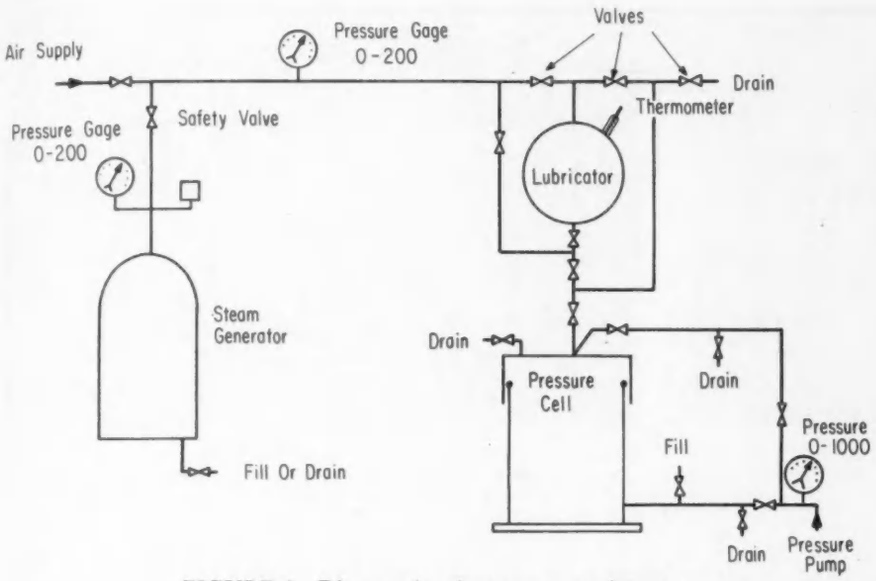

FIGURE 1—Diagram for short core experiments.

Can formation water be shut off for air drilling?

Laboratory experiments directed toward one of the contractor's most perplexing problems indicate that chemical precipitates can reduce core permeability by as much as 93 percent.

By Othar Kiel
Petroleum Engineer, Tulsa

LABORATORY EXPERIMENTS conducted on sandstone and dolomite cores to reduce formation permeability and effect water shut-off in air drilling point to a solution of a serious drilling problem. The experiments indicate that with the proper application of two chemical solutions, each containing a water soluble inorganic material, a precipitate may be formed in the interconnected pore spaces of a reservoir rock.

Tests proved that permeability of the cores which were treated was reduced an average of 99.3 percent. Such results when achieved in the field would greatly reduce water encroachment in air drilling operations and permit the operator to drill with air from top to bottom of the hole.

The chief disadvantage in air drilling is the difficulty in handling any water that is encountered while the well is being drilled. If the volume of water coming into the hole is less than 10 percent of the volume of cuttings being produced, the water is handled along with the cuttings with no difficulty. If the volume is between 10 percent and 35 percent of the volume of cuttings, it tends to ball up the bit. When the amount of water coming into the hole reaches a volume that can no longer be lofted by the compressor power available, air drilling must cease.

There are methods of handling this formation water but all are costly and time-consuming. Casing may be run to shut off the water so that drilling may continue in a smaller hole diameter. Or the well may be mudded up so that drilling may continue in an orthodox manner, and without the advantages of air.

The object of the laboratory study was to attempt to determine a method of reducing the permeability of a reservoir rock to a value at which the fluid produced from such a rock could be lifted economically, along with the cuttings, and thus make it possible to drill with air to depths and in areas hitherto considered impracticable. The approach to reducing the fluids was to attempt to fill the interconnected pore spaces with an insoluble material which could be neither displaced by the hydrostatic pressure of the reservoir, nor dissolved by the small amounts of reservoir fluid which pass through the nearly plugged inner-connected pore spaces.

In other words, since there can be no control on the liquid that a reservoir contains, and since in air drilling there will exist a differential pressure gradient toward the bore hole, the only approach to the problem is to reduce the permeability of the rocks adjacent to the bore hole.

Theory Behind Experiment. In an aquifer, it is possible to have a pressure differential across two adjacent strata. The plugging material must set or form in a short space of time in order that it will not be displaced further into one stratum because of this pressure differential. This plugging material must also set rapidly so that it can be placed in each stratum of the formation regardless of the permeability of each. As the permeability in one stratum is reduced, the penetration of the plugging material will occur in another stratum until finally there is sufficient penetration in all the beds to reduce the over-all permeability of the entire reservoir in the proximity of the bore hole sufficiently so that fluid production will not be a problem.

The material must not contain any particles which will filter out at the face of the bore hole, and it must have a low enough viscosity so that it can

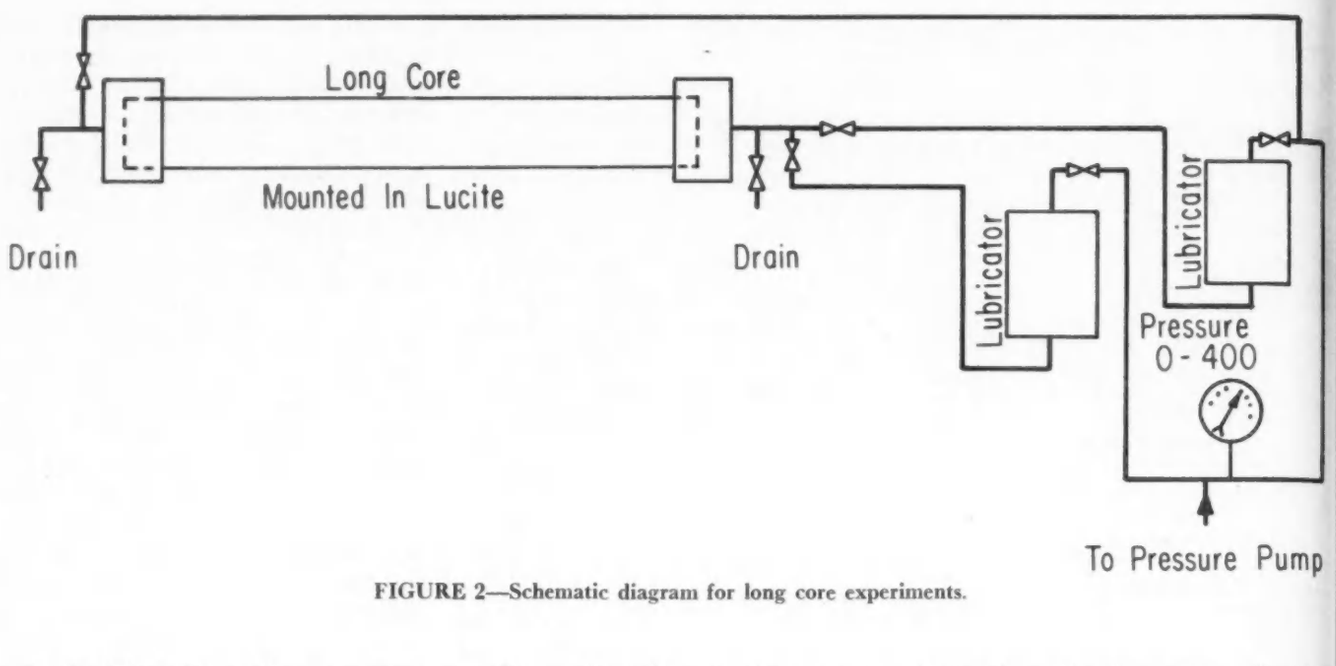

FIGURE 2—Schematic diagram for long core experiments.

easily be injected into the pore spaces of the reservoir rock.

It must also be of such a nature that the drill pipe, or other pipe through which the material is injected, will not become plugged. In other words, this material must not set in a drill pipe or in the well itself to an extent that mechanical difficulties will result.

The method must also be of such a nature that the process can be stopped at any time without affecting its outcome. This requirement must be met because of the many unavoidable delays which can occur at a well site due to failure in equipment, neglect in part of the process, or to some oversight of the personnel.

The material used must be of an insoluble nature so that if a shut-off is not complete there will not be an increasing permeability to the formation fluids from the gradual solution of the plugging material in the interconnected pore spaces with time.

It must also be strong enough to withstand reservoir pressures.

Apparatuses Used in Experiment. One apparatus that was used consisted of a pressure cell for simulating reservoir conditions, a lubricator for injecting material into the core, and a system of piping to handle the material in the lubricator in various manners before injection into the core. A schematic design of this apparatus is shown in Figure 1.

The other apparatus consisted of two lubricators which were connected at the top by tubing to the pressure pump and connected at the bottom by tubing to the long cores which were studied. Valves were arranged so that alternate slugs of solution from the lubricators could be injected into the long cores. A schematic design of this apparatus is shown in Figure 2.

It was decided to work on a material soluble in an organic solvent, and pairs of liquids which would

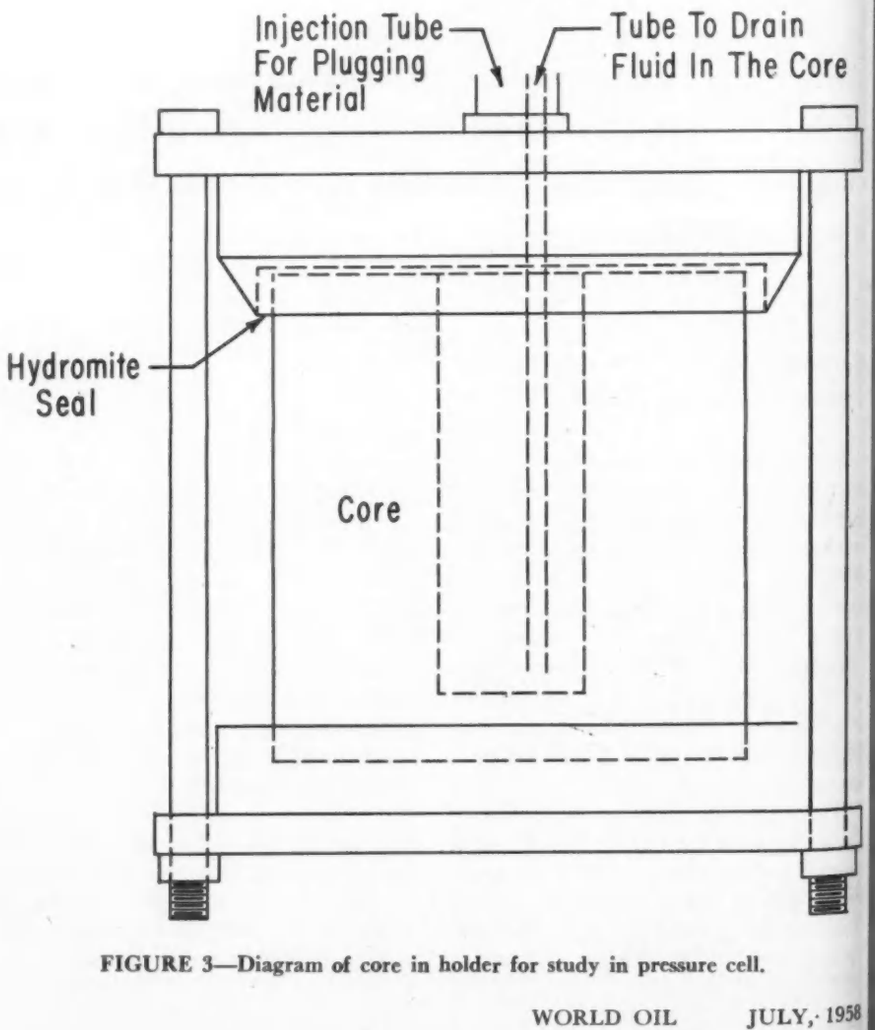

FIGURE 3—Diagram of core in holder for study in pressure cell.

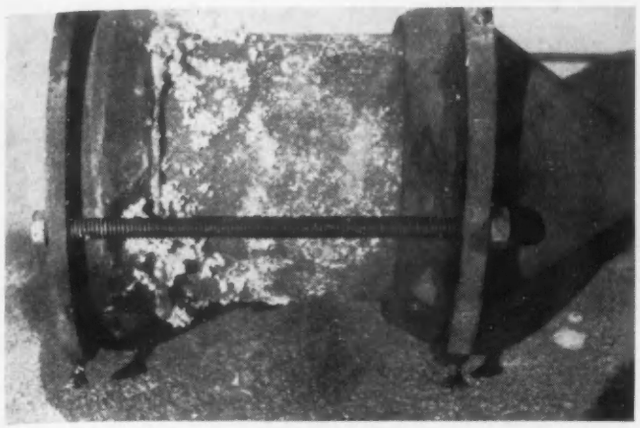

FIGURE 4—The above pictures show results obtained on a sandstone core in which the plugging agent, dichlorobenzene, was used during the experiment. The photograph at the left shows how the plugging agent emerged from the pores of the core. The photograph at the right shows how it was concentrated in an incipient fracture. Permeability of this core was lowered 91 percent.

form an insoluble precipitate. The cores to be studied in the pressure cell were mounted as shown in Figure 3; the top of the core was set in a stiff hydromite slurry for a pressure tight seal and bolts were used to hold the core in this position. The long cores were mounted in a lucite tube using a process involving heat and pressure.

The solution containing the plugging material was placed in the lubricator after closing the bottom valve. Air was used to purge the system of as much water as possible and then with the proper arrangement of valves the solution in the lubricator was forced into the core.

The long cores were mounted so that pressure could be applied at either end. A pressure of some three hundred pounds was used on each core and alternate slugs of the plugging material were injected into the core from the lubricators. (Figure 3)

Each core was flushed with fresh water before experimentation. The permeability was reduced during the flushing process. The permeability was not reduced if the core had first been flushed with a calcium chloride solution. So, after the first long core was worked with, all of the subsequent long cores were first flushed with a calcium chloride solution.

The permeability of each core examined was actually determined before and after an experimental run. This data was used as the criterion of the success or failure of the method.

Several slides of cores that had been plugged were prepared and examined under the microscope.

Results. When an organic material soluble in a water miscible organic solvent was considered, acetone was used as the water miscible solvent and either paradichlorobenzene or fluorene was used as the organic material. Several experiments were performed using each of these organic materials separately. When the paradichlorobenzene solution was poured into water, a dense mass of dichlorobenzene formed in the water. When the fluorene solution was poured into water, some solids formed, but for the most part the resulting solution was a milk-like suspension.

When an organic material in a water miscible organic solvent was employed as a plugging material, Table 1 (a) and (b) shows that the core should be completely full of the the solution to obtain a good reduction of permeability. However, there was a reduction in permeability of 57.25 percent when the core was only partially filled with this solution. Table 1 part (c) shows that fluorene is not as good a plugging material as dichlorobenzene. When fluorene was employed in the core it was readily washed out of the pore spaces of the core when pressure was applied for permeability tests.

In part (c) and (d) of Table 1, employment of dichlorobenzene resulted in lowering the permeabilities an average of 93.25 percent.

The method of mixing two aqueous solutions, each of which contained a water soluble material, in the long cores to form a precipitate gave good results. For this method, three materials were used. They were trisodium phosphate and a silicate colloid each of which will form a precipitate with calcium chloride. Each pair of solutions (i.e. calcium chloride with trisodium phosphate and calcium chloride with the silicate colloid) was tested in a beaker before being used in the long cores. Each pair of these solutions formed a dense precipitate which required several minutes to form. The time of formation of the precipitate depended upon how thoroughly the two solutions were mixed. The more thorough the mixing, the shorter the time required for formation of the precipitate.

It was believed that calcium chloride should be used even though there is a possibility that some calcium ions are already present in the rocks to be plugged. This belief was at least partially substantiated because the permeability of the cores was lowered when either the triso-

TABLE 1—Results of Permeability Data

CORE	Original Permeability	Final Permeability	Treatment
(a)	5.24	2.27	Dichlorobenzene in acetone core not filled with solution
(b)	0.229	0.01	Dichlorobenzene in acetone core filled with solution
(c)	0.275	0.190	Fluorene in acetone core filled with solution
(d)	6.80	0.561	Dichlorobenzene and acetone core filled with solution
(e) Long Core B	46.5	0.342	Na_3PO_4 $CaCl_2$
(f) Long Core D	49.0	0.57	Colloidal silicate and $CaCl_2$
(g) Long Core F	158.4	.53	Colloidal silicate and $CaCl_2$
(h) Long Core G	256	1.09	Na_3PO_4 $CaCl_2$

dium phosphate or the colloidal silicate was injected.

In a long core the permeability was reduced 72.6 percent when the sodium phosphate was injected. When calcium chloride was then injected, the permeability was reduced 96.95 percent. After another injection of trisodium phosphate a 99.5 percent reduction of permeability was measured.

Microscopic study showed that the precipitate from these two solutions had formed a dense mass which adhered to the sand particles and filled the pore spaces of the core.

When the silicate colloid and calcium chloride solutions were used, the silicate colloid was injected first in the long core. Again, with the silicate colloid alone the permeability was reduced 94.76 percent. The employment of calcium chloride following the silicate colloid resulted in a 99.8 percent lowering of permeability.

Microscopic study of this core showed that the precipitate which formed was a mass that did not adhere to the sand particles, but rather had probably formed a mechanical bridge in the pore spaces of the core. When the core was sliced and the slice was washed with water to remove the dirt formed during the slicing process, the precipitate was also washed from the surface of the slice to be studied. The microscopic study of this core was then inconclusive as to results.

Discussion of Results. The results of the study show in which direction a possible solution for this problem may be found.

While working with an organic material in an organic solvent it was realized that perhaps one of the original assumptions was at least partially in error. Since each time that the plugging solution was passed through the core, the permeability was reduced, it was decided that the solution did not have to be highly saturated with the plugging material. In view of the fact that all of the water had to be displaced with air from the core before injecting the plugging material, it was decided to try the method of several applications using an inorganic material dissolved in water. This would obviate the fact that all of the water should be removed from the hole and that the water in the hole would dilute the solutions so that they would no longer be effective. Use of inorganic materials would also eliminate temperature as a limiting factor of the method. Most of the suitable organic materials melt at a fairly low temperature while the inorganic materials melt at higher temperatures.

In the long cores, the permeability decreases with the injection of either the trisodium-phosphate or the colloidal silicate. Since this permeability decrease is from a high to a lower value, the material injected enters all portions of the core that have permeabilities between these values. And since the calcium chloride injection which follows this injection will lower the permeability further, the entire range of permeabilities in the hole will be reduced. Thus it is possible that stratification can be successfully coped with.

Conclusions. These results show that with the proper application of two solutions, each containing a water soluble inorganic material, a precipitate may be formed in the interconnected pore spaces of a reservoir rock. It is further shown that the permeability of these cores was reduced an average of 99.3 percent.

ACKNOWLEDGMENT

The writer wishes to express his gratitude to Robert Murphy and William Randall of Pan American Petroleum Corporation, Tulsa, for their interest and their help in obtaining material for this article. Appreciation is also extended to Dr. F. T. Gardner and Prof. E. A. Howard, whose help and advice were a considerable benefit on numerous occasions. Special appreciation is extended to Dr. E. T. Guerrero, under whose guidance this work was performed.

About the Author

Othar Kiel received a B.S. degree from Mt. Union College, Alliance, Ohio, in 1939. After graduating he taught school for a year. During World War II he was chief pilot for an Army contract school at Canton, Ohio. Following the war he joined his family in the oil business until 1956 when he entered Tulsa University from which he graduated in 1957 with an M.S. degree in petroleum engineering. He is now associated with The Carter Oil Company's Research Center, Tulsa.

How good a driller are you?

A quiz for oil field folks. Score as follows: 0-4 (Weevil); 4-8 (Mud Doctor); 8-10 (Expert). One point for each correct answer. Answers at bottom of page.

1. **The hole volume (barrels) of a 10-inch diameter hole 4000 feet deep in about:** a. 40 b. 400 c. 650
2. **The weight of water in pounds per gallon is:** a. 6.5 b. 8.33 c. 10
3. **The end point in the chloride test is a change from yellow to:** a. colorless b. orange c. blue
4. **Which of the following is not mud testing apparatus?** a. Marsh funnel b. filter press c. shale shaker d. mud balance
5. **Match the following chemicals in one column with their chemical composition:**

a. Caustic soda	1. . . . . barium sulfate
b. Soda ash	2. . . . . sodium carbonate
c. Barite	3. . . . . calcium sulfate
d. Anhydrite	4. . . . . calcium oxide
e. Quick lime	5. . . . . sodium hydroxide

ANSWERS

1. b; 2. b; 3. b; 4. c; 5. 1, c; 2, b; 3, d; 4, e; 5, a.

At 13,000 ft in the Caillou Island Field. The barge *Garry*, lonely outpost in these Gulf Coast waters, is equipped for deep and difficult offshore drilling. The job shown here is typical, with the hole at 13,000 ft and another 1600 ft to go. Location: Caillou Island Field, off the Louisiana mainland.

The *Garry* was custom-built for the Buster Gardner Drilling Co. Because of the heavy loads involved in handling the drill pipe, the owners specified Bethlehem rotary line in the 1⅜-in. size. (At the time of the photograph, this husky wire rope had accounted for 62,000 ton-miles and 55,000 ft of hole.) Also included in the *Garry's* equipment is 9/16-in. Bethlehem coring line with the rust-resistant bethanized coating.

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Here are considerations for . . .

Optimum water-flood development

Optimum development of a water-flood project is dependent on reservoir mechanics and basic development controls.

By Bert Murphy
Water-Flood Associates, Inc., Fort Worth

CAREFUL DEVELOPMENT planning is necessary to realize maximum profits on a pattern water-flood project in primary depleted or near depleted fields. Each project has individual, complex problems that cannot be solved by a universal formula. The best program selection must be made by a systematic trial and error analysis. Considerations fundamental to this analysis are divided into two main groups: flood practice and reservoir mechanics and the basic controls influencing development planning.

If well concentration in any given project area is increased, development costs for the project will increase but project life will decrease. For relatively wide ranges of development programs, operating costs are more a function of project life than any other factor. Since development and operating costs are therefore inversely proportional as spacing is changed, an optimum development plan exists where their sum is a minimum and profits a maximum.

Basic controls for selection of all feasible development plans for any one project include: existing facilities, geological considerations, land considerations, state regulations and the working interest financial structure and position. After these are considered and all feasible programs are analyzed with regard to project economics, the optimum development will be apparent.

Flood practice and reservoir mechanics. Good flood practice has developed from experience and has been partially explained by laboratory and theoretical work. Not all operators agree as to what constitutes good practice. However, all agree that facilities must deliver a proper water (one which will not corrode equipment or plug the formation) to that portion of the formation that contains the oil and through the oil zone only. They further agree that the project should be continually operated in such a manner that a maximum amount of water will be injected into the reservoir without creating excessive pressures which would tend to by-pass water by "formation breakdown."[1]

Experience and theoretical work has indicated that dimensionless oil production rate as related to time is largely dependent upon permeability variations of the productive section. The theory suggests that the most permeable parts of a section flood-out first and then produce injected water. This procedure continues with the successively less permeable parts flooding out and producing water until an uneconomical water cut is reached. In properly operated high rate floods, close agreement has been found between theoretical flood performance predictions based on permeability variation and actual flood performance. (Figure 1.)

Theoretically, if geologic and economic considerations are ignored, well geometry and fluid mobility ratio mainly control areal coverage for the various flood patterns. Actual distance between wells is unimportant to ultimate recovery and dimensionless flood performance. Therefore, if geologic and economic considerations are ignored, actual distance between wells for any given pattern is essentially independent of recovery, water injected, water produced and dimensionless time performance of the project when good flood practice has been followed. "Essentially independent" was used above due to a reduction in rate for the same pressure differential as spacing is increased. Fortunately, the effect of distance between wells on rate appears in the flow equation as a reciprocal of a logarithmic factor. For example, there is only approximately a 6 percent rate reduction with doubled spacing when comparing a 20-acre (660 feet) and 80-acre (1,320 feet) five-spot.[2]

In accordance with the above, flood-out time of a given project will be approximately equal to the amount of water that must be injected to produce the ultimate recovery divided by the average injection rate per injector times the number of injectors. As previously indicated, the amount of water to be injected and the recovery are essentially constant for practical ranges of spacing so that flood-out time varies with average injection well capacity and number. Although the phenomenon of formation breakdown has not been completely explained, well spacing has not been observed to be a major function of its variation. Consequently, for any given project injection rate on a per well average basis will be essentially constant within practical spacing ranges if good flood practice is followed and relatively uniform reservoir conditions exist over the project area. Flood-out time is essentially inversely propor-

Existing facilities influence development costs

tional to the number of injectors for any given project and pattern where sufficient producer capacity (as in the five-spot program) exists. If basic controls are not considered, optimum development would consist of a pattern and spacing where the sum of development and operating cost are a minimum and profit is a maximum. However, basic controls must be considered before this determination can be made.

Basic controls on development. Facilities existing on a proposed project will influence development cost. There may be wells and other facilities that must be abandoned or that can be used to partial or full advantage. These facilities will determine to some extent the selection of feasible programs by the planner.

Geologic considerations are most important and require careful detailed study. Lenticularity, permeability trends, and multiple productive zones will influence well spacing and pattern. Lenticularity may set the limit on spacing while permeability trends set the pattern in some projects. In large projects where well capacity varies from area to area, it may be necessary to vary spacing for best results.

Arrangement and ownership of the leases that compose the project area may affect development. If the fee ownership varies greatly between leases, efficient economic well spacing may be sacrificed to protect lease lines. Inefficiency in oil gathering and storage systems, operating, etc., may also result. Study is necessary to determine where the cost and delay concerned with full or partial unitization of royalty interests are exceeded by the advantages.

Off-setting operations will affect development to the degree that the offsetting operator will or can cooperate. In general, however, the author believes from observation that efficiency will be served if working interests are not unitized unless absolutely necessary.

State and other regulatory bodies can be an important control depending on the location of the flood.

Working interest, financial structure and position, including the Federal Income Tax factor, may exert a great influence on development planning. In most analysis the tax factor should be included and the overall financial situation of the working interest considered to determine the effect the project will have and how to make it most favorable.

Economic considerations. Operating costs are more a function of time for any given project area within practical limits of development density than any other factor. Development costs are more a function of well density than any other factor. As spacing is increased, development costs decrease. Since project time therefore increases, operating costs increase.

Disregarding the basic controls, development and operating costs are inverse functions as spacing is changed. A development plan exists where their sum is a minimum.

Cost estimates should be made in detail. The development cost will contain those items that are primarily a function of the development plan. These would include the following:

- Well Work
  - new injectors
  - new producers
  - conversions of producers to injectors
  - recompletions to injector
  - recompletions to producer
  - workovers of producers for the program
  - plugging or replugging old wells
- Facilities should be planned of sufficient quality and capacity to serve each well development considered so that good flood practice can be followed. These include:
  - water supply system
  - injection plant and facilities
  - water distribution system
  - oil processing and storage facilities

While operating costs are often quoted as dollars per well per month or per barrel produced, these are only useful rules of thumb. Actual operating

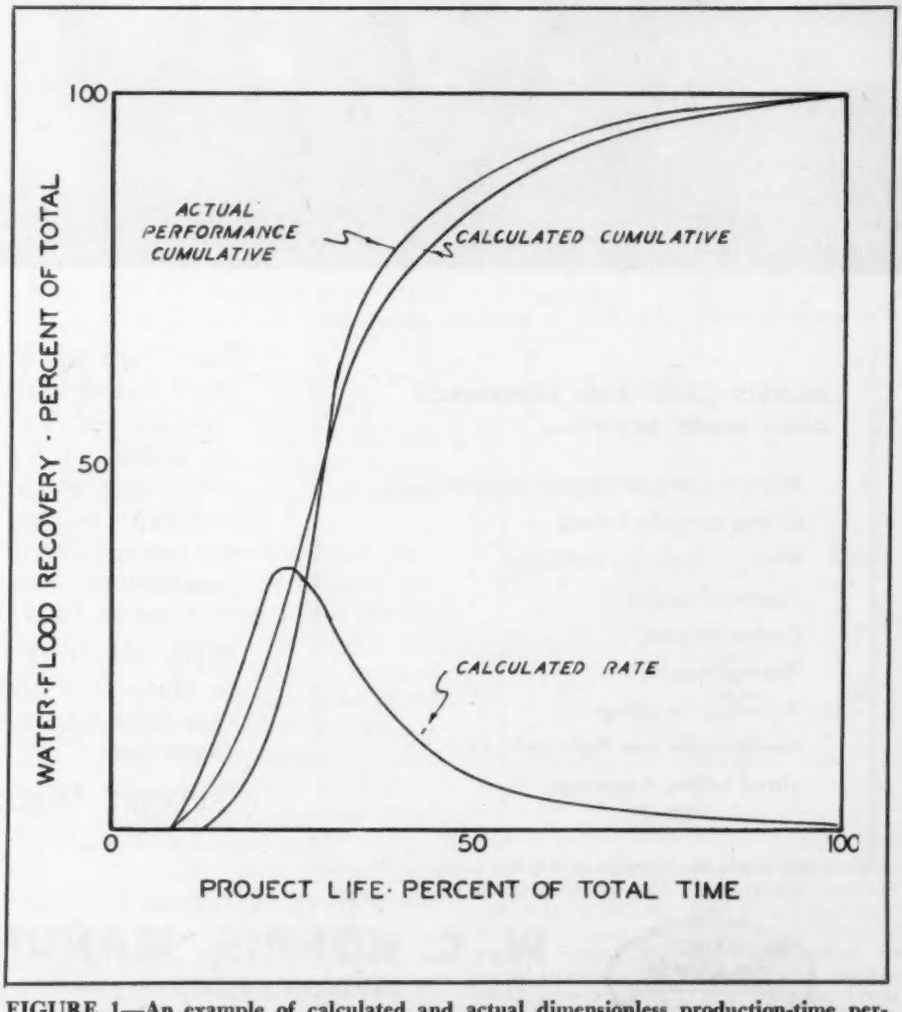

FIGURE 1—An example of calculated and actual dimensionless production-time performance for a project using good flood practice is shown above. The dimensionless oil production rate is primarily a function of permeability variation.

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Good experience aids in determining flood-out time

cost should be calculated for each development plan considered. These costs include the following:

Item
1. Supervision & Engineering
2. Overhead
3. Labor
4. Transportation
5. Power, Fuel & Water
6. Repair & Maintenance (Prorated)
7. Remedial Workovers (Prorated)
8. Operating Supplies

Main Dependence For A Given Project Area
1. Organization, Size and Complexity of Project
2. Same As Above
3. Group of Facilities Per Unit Labor: Number of Groups
4. Supervision & Labor Force: Same as (1) & (3)
5. No. of Wells, Complexity of Facilities, Production
6. Same as Above and Flood Life
7. No. of Wells and Flood Life and area Conditions.
8. Same as (5)

Items 1 thru 4 are generally a large percentage of monthly operating cost. They are more dependent on project size, complexity and unit groups of facilities than on the actual number of wells, or barrels produced. Thus, in some cases, the actual number of wells can be increased or decreased several fold without appreciably changing monthly operating cost. This would result within reasonable limits, in total project operating cost being more nearly a function of length of project life than number of wells or barrels produced.

Determining optimum development. In actual practice the following procedure is recommended for program determination:

- A careful study of the basic development controls should be made with regard to the area to be developed. Steps should be taken to make these controls as favorable as possible, i.e., land and legal work, etc.
- All feasible development programs should be determined. Flood performance and cost predictions should be made for each. Included should be studies of programs that would use existing facilities and wells and those that would plug out and completely redevelop the leases. All feasible patterns and spacings should be considered.
- Each feasible program should be subjected to an economic analysis. Overall working interest economic structure and position, the income tax factor and present worth of money should be considered. The best program can then be selected.

It is necessary to determine flood-out time for various development programs. This study can be made as complex or as simple as time and data permit. Good experience data (usually available on comparable properties) can be used as an aid in determining required predictions. If core and other reservoir data are available prior to the study, the classical and/or improvised methods employing reservoir data may be used both as a check on area experience and/or as independent predictions. It should be remembered that there may be some latitude in the correctness of the reservoir study and still permit correct selection of project development. For example, in studying development Plans I thru VI (Figure 2) time was predicted as 2.5⁻Y to 80.0⁺Y years and Plan III as optimum. The actual flood-out time might be 3⁻Y thru 90⁺Y years. In actual practice these plans would have been chosen for study considering the basic controls and would be fixed as the most reasonable plans due to these controls. In all probability Plan III would be the correct choice even though the time prediction might be incorrect by 10 to 20 percent. If a pilot flood is conducted with careful performance data control (with adequate field data collected) the original development program can be reviewed and modified when the flood is expanded.

Considering present worth and taxes, it will be necessary to construct a predicted production curve. It is not the purpose of this paper to consider specific methods to be used in arriving at the above factor. It should be noted however, that these predictions are made by one or a combination of, three general methods: analogy to local experience, laboratory analysis or classical theoretical calculations.[3,4]

Local experience combined with good field control data is generally preferred to classical theoretical calculations. All reasonable methods that will help determine performance should be used. In predicting a production curve, a dimensional curve showing percent

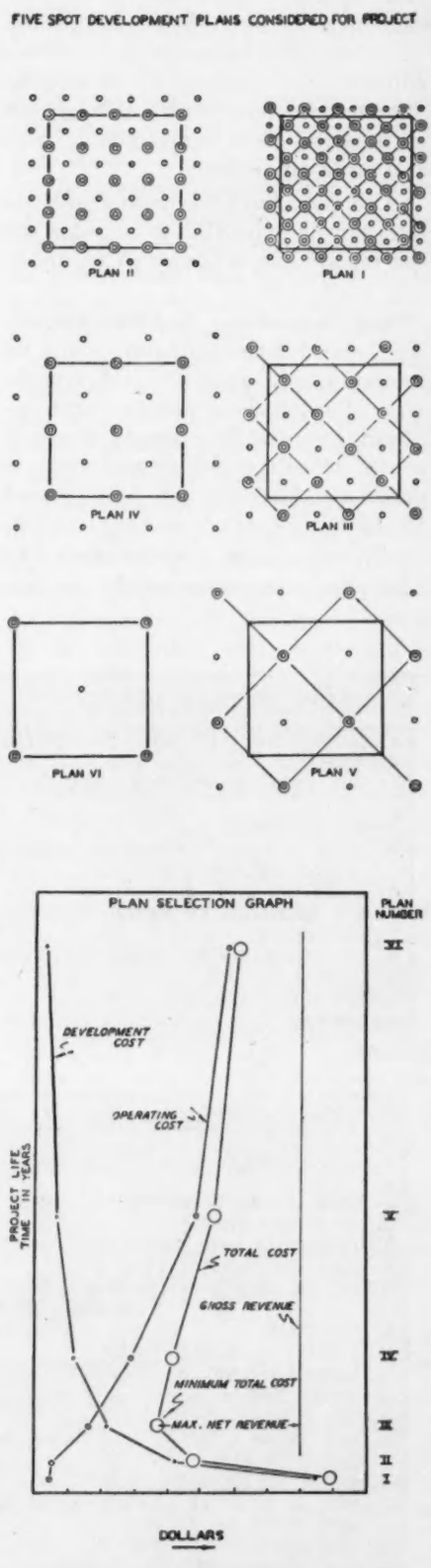

FIGURE 2—Illustrated above is a graphic presentation of basic development analysis results for a uniform sand area where only new development is done on a five-spot pattern. Offset cooperation was good. In actual practice basic development controls could greatly modify this analysis. From the plan selection graph, Plan III was predicted as optimum.

of total secondary oil to be recovered as a function of the percent of total time necessary for recovery may be made from area experience, and a study of permeability variation. After differentiating the cumulative function to get rate by increment time, this method of presentation is easily used in trial and error predictions.

A simple form for economic analysis that can be expanded to consider the specific analysis is shown in Figure 3.

Other economic considerations. The systematic economic analysis method can be applied to other problems of water-flood practice with interesting results. As example, Figure 4 shows the effect of increased reserves on profits. Although only a 50 percent increase in reserves is considered, profits are almost doubled since the additional reserves are nearly cost free compared to the lower reserve figure. As would be expected optimum spacing has not changed. A large increase in reserves however, could in some unusual cases change development spacing. This would occur when additional development costs for higher capacity equipment would force closer spacing to reduce operating, and, therefore, total cost to the minimum.

Figure 5 shows the effect of project size. For any area and type development there is an approximate minimum cost somewhat independent of project size for flooding. As project size is increased increment cost per acre decreases. Profits per acre increase and approach some fixed percentage of gross revenue per acre. The decrease after a maximum does not indicate that total profits will decline or that a project should be limited to a set number of acres. It shows only that surface lines and facilities reach an optimum at a certain acreage development. This decrease can be eliminated by proper surface facility selection and distribution over the project area. It is possible that intangible factors of organization efficiency, etc., could also effect profit per acre as a function of project size in the same manner as shown in Figure No. 5. Thus, the antipathy to large working interest units.

Conclusions. The following has been concluded for pattern water-floods of primary depleted or near depleted reservoirs where good flood practice is followed:

1. Optimum development is dependent on reservoir mechanics and basic development controls.

Continued on Page 143

BEFORE INCOME TAX ANALYSIS (REF. 5)	TIME · YEARS 1ST	2ND	3	LAST	TOTAL
1. GROSS PRODUCTION, BBL. (TIME SPREAD PER STUDY)					
2. NUMBER OF WELLS INJ./PROD. WORKING INTEREST CONCERNED					
3. PRODUCTION, BBLS.					
4. GROSS INCOME AFTER MINERAL TAXES, $					
5. DEVELOPMENT COST, $					
6. OPERATING COST, $					
7. NET INCOME BEFORE INCOME TAX & SALVAGE, $					
8. SALVAGE, $					
9. NET INCOME BEFORE INCOME TAX AFTER SALVAGE, $					
10. CUMULATIVE, $					
11. (9) DISCOUNTED, $					
12. CUMULATIVE, $					

AFTER INCOME TAX ANALYSIS (REF. 6 & 7)	TIME · YEARS 1ST	2ND	3	LAST	TOTAL
WORKING INTEREST CONCERNED					
1. GROSS INCOME AFTER MINERAL TAXES, $					
2. OPERATING COST, $					
3. INTANGIBLE DEVELOPMENT COST, $					
4. EQUIPMENT DEPRECIATION, $					
5. NET INCOME FOR TAX PURPOSES, $					
6. DEPLETION (SELECT ALLOWABLE) — STATUTORY 27½% GROSS, $ / 50% NET, $ / COST					
7. TAXABLE INCOME, $					
8. INCOME TAX, $					
9. (8) AS PAID, $					
10. NET INCOME AFTER AS PAID INCOME TAX BEFORE SALVAGE					
11. AFTER TAX SALVAGE					
12. NET INCOME AFTER AS PAID INCOME TAX WITH AFTER TAX SALVAGE					
13. CUMULATIVE					
14. (12) DISCOUNTED					
15. (14) CUMULATIVE					

FIGURE 3—This simple form for economic analysis can be expanded to consider the specific analysis.

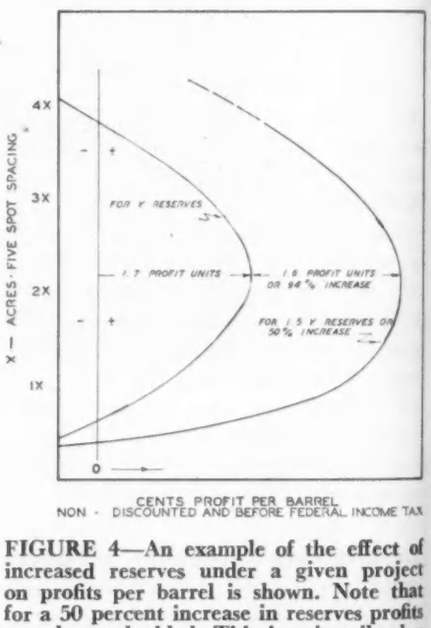

FIGURE 4—An example of the effect of increased reserves under a given project on profits per barrel is shown. Note that for a 50 percent increase in reserves profits are almost doubled. This is primarily due to the additional reserves being cost free as compared to the original reserve estimate.

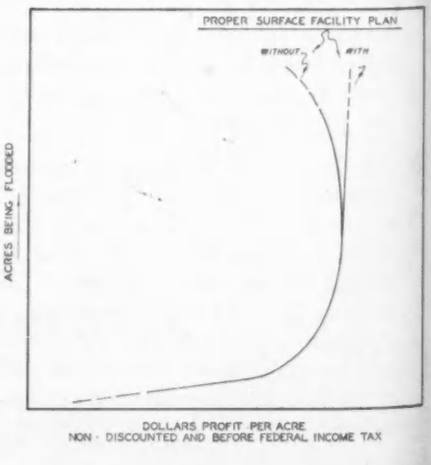

FIGURE 5—(Right) The effect of project size on profit per acre is illustrated. The decrease after a maximum shows only that surface lines and facilities reach an optimum at a certain acreage development. This decrease can be eliminated by proper surface facility selection and distribution over the project area.

Fresh water fracturing can cut treatment costs

Both new and old wells completed in high content formations respond favorably to fresh water fracture treatment.

By R. E. Hurst, J. T. Rollins and H. A. Stewart
Dowell, Midland, Texas

THE USE of fresh water as a fracturing fluid can be considered as an established practice on the basis of data from the first 100 fresh water fracturing treatments in the Permian Basin. Emulsion difficulties, silicate swelling and fluid loss can be controlled by adding properly selected agents to the treating water. In most cases, using fresh water as the fracturing fluid will substantially reduce the cost of fracturing treatments. In formations with high salt content, both new and old wells can be expected to respond well to the use of fresh water. Old wells which have produced high-salt-content crude oil and formation water over a period of time can also be expected to respond favorably to the use of fresh water.

The use of fresh water as a fracturing fluid in oil reservoirs became widespread in the Permian Basin in 1956, following its earlier introduction in the San Juan Basin. Although water was first used because of its economy, it soon became apparent that water often gave better production increases than oil-base fracturing fluids. Investigations showed that these improved results were caused by the action of fresh water in dissolving and removing salt from treated formations.

Salt occurs in reservoir rocks as matrix material, pore-filling material, fracture-filling material and as a precipitate from crude oils or brines. The salt content of a core sample can be determined by petrographic study or by chemical tests. Examinations of thin core sections show not only how much halite (salt) is present but also if the halite is in the form of cementing material, individual crystals or secondary deposition in pores, channels or natural fractures.

Figure 1 is a photomicrograph (X300) of a halitic sandstone thin section from an upper Permian formation. Halite is the cementing material binding together chert and quartz grains. At the upper left hand corner, marked "C," is a chert grain. The grains marked "Q" are quartz, and the black grains at upper right are magnetite or ilmenite. The arrows point to characteristic cubic openings in the halite. Others are between the arrows and below them. The opening at the right arrow contains a gas bubble. Many more such openings are in the sample, but they cannot be brought into focus at such high magnification.

Figure 2 is a photomicrograph (X69) of loose quartz sand grains from the same core sample after the cementing halite was removed. This is the effect that can be expected when fresh water is used in treating such a formation.

The presence of halite as individual crystals in the formation is shown in Figure 3, a photomicrograph (X300) in which both halite and quartz grains are prominent. It is apparent that halite grains may be as large or larger than quartz grains. Dissolving and removing many such halite grains during a fracturing treatment using fresh water will substantially increase formation permeability.

Preparing samples for petrographic studies is a time-consuming process. A quicker way to determine the salt content of a core sample is to crush a known volume of rock from the center of the core, then soak it in distilled water. The salt content of the water is then measured so that the total amount of salt in the sample can be calculated. From the original water saturation of the rock and the salt content of such water, the amount of salt in the sample resulting from water evaporation can be determined. This amount is subtracted from the total salt content, giving the original salt content of the formation rock itself.

A simple field test to determine whether salt is present can be made by putting a few drops of distilled water on a freshly broken core surface, dropping a small crystal of silver nitrate into it and observing the appearance of the crystal. If the rock has a high salt content, the crystal will quickly cloud over. If only a little salt is present, white streamers of precipitate will form in the water around the crystal.

Many crude oils hold large amounts of crystalline salt in suspension. Figure 4 is a photomicrograph of crude oil, from the Upper Clearfork formation, containing 132 pounds of salt per 1000 barrels of oil. Tests have shown that crude oils may contain from less than 5 to more than 1200 pounds of salt per 1000 barrels.

The use of water containing from 2 to 4 percent hydrochloric acid has proved valuable in many reservoirs. Such a low acid concentration makes it possible for the fluid to dissolve salt and remove limestone simultaneously.

Analyses of returned water follow-

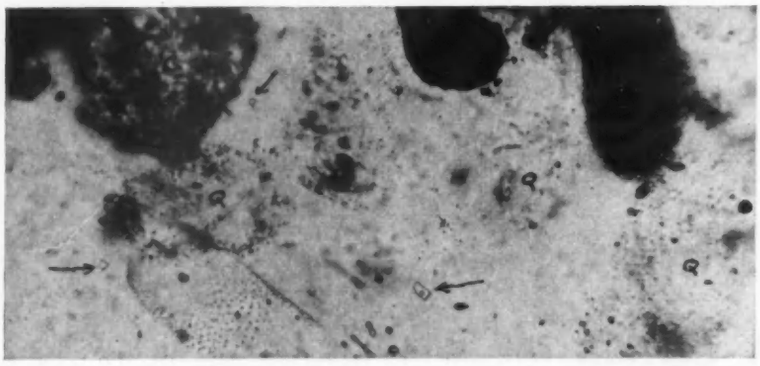

FIGURE 1—Photomicrograph (X300) showing halite as the cementing material in a core. Arrows point to typical cubic openings in the halite. Chert and quartz grains are marked "C" and "Q," respectively. The black grains at the top right are magnetite or ilmenite.

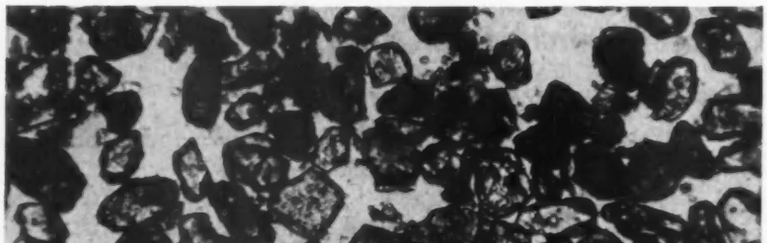

FIGURE 2—Photomicrograph of loose quartz from the core sample is shown in Figure 1 after the cementing halite has been washed out.

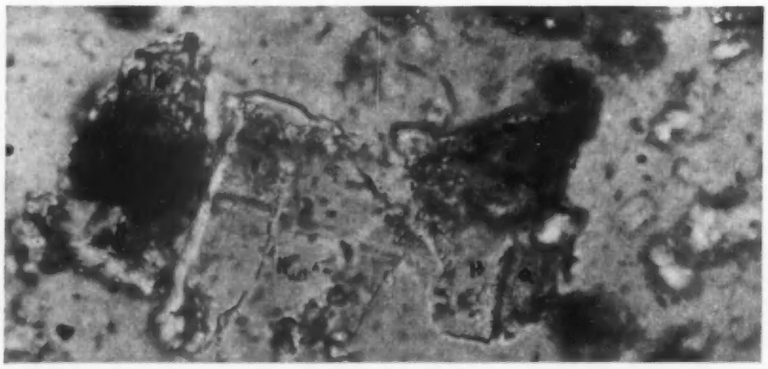

FIGURE 3—Photomicrograph (X300) of crystalline halite in a Queens sandstone of Permian age.

FIGURE 4—Photomicrograph (X200) of salt crystals in crude oil, from the upper Clearfork formation.

ing fresh water fracturing treatments have repeatedly shown that salt was actually being dissolved and removed from the formation. A test was run under carefully controlled conditions to determine how much salt in the returned water came from formation brine and how much was dissolved from flow channels or formation rock. A well was treated using 20,000 gallons of fresh water containing 50 ppm iodine. An accurate record was made of the quantity of returned water, and frequent samples were taken to determine both the salt and iodine content of the returned water.

The percentages of injected and formation waters present in the recovery were determined from the concentration of iodine in the returned water. The salt content of the formation water was known to be 5.2 percent. From this data, given in Table 1, it was calculated that the fresh water had dissolved and removed from the formation 1869.2 pounds of salt. The removal of such a large quantity of salt greatly increases the effectiveness of a fracturing treatment.

The probable effectiveness of a fresh water fracturing treatment can be predicted from the salt contents of the formation rock, produced crude and produced brine. Table 2 lists these characteristics for a number of formations. In the Shafter Lake pool, Yates formation, the produced crude contains 460 pounds of salt per 1000 barrels. The salt content of the produced water is 13.5 percent, and the formation rock contains 29 pounds of salt per cubic foot. Fresh water fracturing should greatly benefit old wells in this area because of the high salt content of the rock and the salt deposited from produced crudes. New wells in this formation should also benefit greatly from water treatments because of the rock's high salt content.

Previous acid treatments in this area did stimulate production upon original completion, although much of the acid was returned unspent because this sandstone is not acid-soluble. However, the 15 percent acid used could dissolve a considerable amount of salt. It is believed that the results obtained on initial completions were due to the removal of salt. Wells in this area do not produce water. The returned water following fresh water fracturing treatments here has been salt-saturated, and, after the

treating water was recovered, these wells stopped producing water.

Formation Analyses. In the Wheat Pool, Delaware formation, salt content of the produced crude was 4.2 pounds per 1000 barrels. Produced brine contained 17.6 percent salt, and the salt content of the formation rock was 1.2 pound per cubic foot. Acid solubility of the rock was 5 percent. Because of the low salt content of the crude, it is unlikely that much salt would be deposited in formation flow channels in old wells. However, because of the high salt content of the rock, it can be expected that fresh water would be quite effective in fracturing both old and new wells. The use of acid in the fracturing water is probably unnecessary because of the low acid solubility of the rock.

In the Caprock pool, Queens formation, the salt content of the produced crude is 529 pounds per 1000 barrels. Formation water contains 26.2 percent salt, and the formation rock has 1.7 pound of salt per cubic foot. Acid solubility of the formation is 2.3 percent. These facts show that large salt deposits could accumulate in the well from produced crude and brine and that the rock's salt content is fairly high. Therefore, fracturing with fresh water could be expected to stimulate production successfully in both old and new wells.

The salt content of crude from the Grayburg formation, McElroy pool, is 616 pounds per 1000 barrels. The brine contains 3 percent salt, and the formation rock has 0.46 pounds of salt per cubic foot. Acid solubility of the rock is 69 percent. New wells in this area should respond fairly well to fresh water fracturing treatments because of the large amount of salt in the formation. Good results could be expected in old wells because of the high salt content of the crude probably has built up substantial deposits during production. A weak acid solution should be used here in treating new wells because of the acid solubility of the rock. A 3 to 5 percent concentration would be suitable.

Analyses of the Farmer pool, San Andres formation, showed 1233 pounds of salt per 1000 barrels of crude, 17.6 percent salt content in the brine, and 0.24 pounds of salt per cubic foot of formation rock. The rock's solubility in acid is 85 percent. Old wells in this area should respond favorably to water treatments because of accumulated salt deposited from the crude. In treating new wells in this area, weak acid solutions should be used because of the high acid solubility of the rock.

An entirely different situation is presented by the McKee formation in the Goldsmith pool. Produced crude contains only 62 pounds of salt per 1000 barrels. The brine contains only 9.1 percent salt, and the formation rock contains 0.38 pounds of salt per cubic foot. Acid solubility of the rock is 5.6 percent. In this formation it would be expected that oil-base fluids would be as effective as fresh water or water containing acid. The low salt content of the rock indicates that little salt would be removed from it, and the low salt content of the crude oil indicates that very little salt would be deposited in formation flow channels. Acid would not be effective in this sandstone. The choice of a fracturing fluid here would depend entirely upon relative costs.

A somewhat different situation is found in the Dora Roberts pool, Pennsylvania formation. The crude has 5.7 pounds of salt per 1000 barrels. The brine contains 12 percent

TABLE 1

Water Returned From Well X No 3 Farmer Pool, Crockett County

(Water injected 20,000 gal. with 0 salt content and 50 ppm iodine. Formation water content 5.2% salt, or 0.45 lb. per gal.)

Days After Treatment	TOTAL WATER RECOVERED				FORMATION WATER RECOVERED		INJECTED WATER RECOVERED	
	No. Gal.	Percent Brine	PPM Iodine	Salt Content	No. Gal.	Salt Content	No. Gal.	Salt Content
1	3,108	1.50	50	404.0	0	0	3,108	404.0
2	2,310	2.15	50	415.8	0	0	2,310	415.8
3	2,730	2.15	50	491.4	0	0	2,730	491.4
4	1,218	4.30	36	428.5	341	153.5	877	275.0
5	1,260	4.70	14	504.0	908	408.6	352	95.4
6	1,260	5.10	11	554.4	983	442.4	277	112.0
7	1,260	4.90	10	529.2	1,008	453.6	252	75.6
Total Gals. for 7 days	13,146	....	....	3,327.3	3,240	1,458.1	9,906	1,869.2

TABLE 2—Analysis of Permian Basin Reservoirs

POOL	Formation	Salt Content of Crude Lbs./1000 Barrels	Salt Content of Brine Produced, Percent	Salt Content of Rock Lbs./ Cu. Ft.	Solubility of Rock Percent
(Permian Age)					
Shafter Lake, Southwest	Yates (Sandstone)	460.00	13.50	29.00	00.00
Wheat	Delaware (Sandstone)	4.20	17.60	1.20	5.00
Caprock	Queen (Sandstone)	529.00	26.20	1.70	2.30
McFarland	Queen (Sandstone)	500.00	....	1.55	3.00
Means, North	Queen (Sandstone)	78.00	21.50	1.66	3.00
McElroy	Grayburg (Limestone)	616.00	3.00	0.46	69.00
South Cowden	Grayburg (Limestone)	1230.00	5.60	....	....
Farmer	San Andres (Limestone)	1233.00	17.60	0.24	85.00
Harper	San Andres (Limestone)	629.00	7.00	0.26	75.00
Sharon Ridge	San Andres (Limestone)	90.00	11.80	....	....
Slaughter	San Andres (Limestone)	493.00	24.00	0.17	....
Welch	San Andres (Limestone)	966.00	5.70	0.20	70.00
Prentice	Glorieta (Limestone)	197.00	15.20	1.60	....
Andector	Clearfork (Limestone)	135.00	18.00	....	....
Anton Irish	L. Clearfork (Limestone)	255.00	6.70	0.42	....
Prentice	U. Clearfork (Limestine)	197.00	15.80	0.38	....
Sealy Smith	Clearfork (Limestone)	637.00	12.00	0.49	88.00
Goldsmith	McKee (Sandstone)	62.00	9.10	0.38	5.60
Cope	Sprayberry (Sandstone)	40.00	12.30	0.25	3.40
Pembrook, North	Sprayberry (Sandstone)	48.00	11.00	0.40	2.20
Sprayberry, Driver	Sprayberry (Sandstone)	312.00	12.50	0.31	4.60
Block 9	Wolfcamp (Limestone)	12.90	15.20	0.19	83
(Pennsylvanian Age)					
Block 9	Pennsylvania (Limestone)	4.50	13.20	....	....
Dora Roberts	Pennsylvania (Limestone)	5.70	12.00	0.09	93
(Devonian Age)					
Block 9	Devonian (Limestone)	246.00	3.00	....	....
Russell	Devonian (Limestone)	360.00	....	....	....
TXL	Devonian (Limestone)	56.00	14.40	....	....
Yarbrough-Allen	Devonian (Limestone)	82.00	....	....	....
Goldsmith	Fusselman (Limestone)	36.00	13.80	....	....
Sealy Smith	Fusselman (Limestone)	36.00	14.10	....	....
Andector	Silurian (Limestone)	23.00	6.90	....	....
Dollarhide	Silurian (Limestone)	313.00	4.60	....	....
Adair	Ellenburger (Limestone)	10.00	20.80	....	....
Dollarhide	Ellenburger (Limestone)	337.00	4.90	....	....
Dora Roberts	Ellenburger (Limestone)	14.90	7.00	....	....
Goldsmith	Ellenburger (Limestone)	399.00	6.50	0.11	91.5
Midland Farms	Ellenburger (Limestone)	....	....	0.10	92.00
Yarbrough-Allen	Ellenburger (Limestone)	25.00	6.90	....	....

TABLE 3
Prediction Chart

Salt Content of Crude Lbs./1000 Bbls.	Salt Content of Brine	Salt Content of Rock	Predicted Results
H	H	H	E
H	L	H	E
H	L	L	G
H	H	L	G
L	L	H	G
L	H	L	F
L	L	L	F

Crude: H—Over 100 lbs./1000 bbls.
Brine: H—Over 5% Brine.
Rock: H—Over 0.2% or 0.3 lbs./cu. ft.

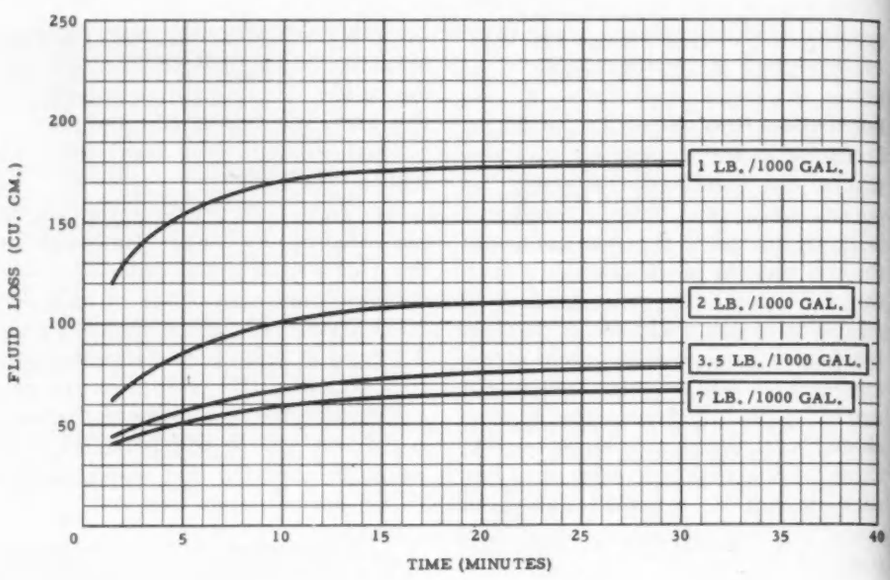

FIGURE 5—Graph of the effect of fluid-loss material on the fluid loss of water. Plain water without special additives has a fluid loss of 600 cc per 30 seconds.

salt, and the formation rock has 0.09 pound of salt per cubic foot. The limestone rock is 93 percent soluble in hydrochloric acid. In this formation, no benefit could be derived from salt removal because of the low salt contents of the rock and crude oil. However, because of the high acid solubility of the rock, weak solutions of acid would be very beneficial in a fracturing treatment. The use of a weak acid solution would be preferable in this case.

A comparison of the results of fresh water fracturing treatments with expected results shows that results have usually been predicted accurately. Table 3 is a prediction chart based on the salt content of formation rock, crude oil and produced brine. From these three factors, the probable effectiveness of a fresh water fracturing treatment can be predicted.

Before carrying out fracturing treatments with fresh water, cores and samples of oil and brine should be analyzed. If such tests indicate that emulsions, formation swelling or water blocks might occur, suitable preventive agents should be added to the water.

Fresh water and most lease oils have a relatively high fluid loss. This fluid loss can be reduced, however, by the addition of a fluid-loss material. For example, the fluid loss of fresh water can be lowered from 600 ml in 30 seconds to 66 ml in 30 minutes by the use of 7 pounds of fluid-loss material per 1000 gallons of water. Figure 5 is a graph showing the effect of various concentrations of fluid-loss materials on the fluid loss of water.

Of the first 100 fresh water fracturing treatments attempted in the Permian Basin reservoir, 92 treatments were completed as planned. Eight treatments were completed with difficulties. A study of these eight failures revealed that one was caused by pipe failure, three were caused by surface equipment failures, and one was due to pressure limitations. Formation lock-up, the ability of the formation to resist receiving additional sand under the pressures and flow rate used during the treatment, also resulted in three failures.

The average sand concentration on these first 100 treatments was 0.985 pound per gallon. This low figure is due to the fact that a few treatments were performed without using sand. The response of these wells was as good as the offset wells which did use sand, but the decline was much more rapid.

Ninety-six wells of the first 100 treatments were treated down casing at an average injection rate of 34.2 bpm. Four treatments were performed down three-inch tubing at an average injection rate of 21.6 bpm. Of the 100 treatments, 79 ranged in size from 5000 to 50,000 gallons, 16 from 50,000 to 100,000 gallons, and five from 100,000 to 500,000 gallons. Ninety-five wells were treated at a depth less than 5000 feet; the other five were treated at depths between 5000 and 10,000 feet.

Increased production, with an indication of a pay-out and a profit, resulted from 78 of the 100 treatments. No change in production was shown by 16 wells; however six wells showed a production loss, in most cases being less than 1 bopd.

Wells which did not show produc-

Continued on Page 143

TABLE 4—Breakdown of Results by Formations

FORMATION	Number of Treatments	Number Successful	Average Production Before Treatment		After 7 Days		After 30 Days	
Red Sandstone	1	1	0.0 Oil	0.0 Water	24.0 Oil	5.0 Water	24.0 Oil	5.0 Water
Queen Sandstone	7	7	6.5 Oil	0.3 Water	32.0 Oil	16.1 Water	35.6 Oil	3.1 Water
Yates Sandstone	26	25	2.5 Oil	2.2 Water	37.0 Oil	31.3 Water	32.1 Oil	23.0 Water
Seven Rivers Sandstone	1	0	0.0 Oil	0.0 Water	0.0 Oil	200.0 Water	Plug and Abandoned	
Delaware Sandstone	6	5	3.1 Oil	14.0 Water	13.0 Oil	284.0 Water	10.8 Oil	69.1 Water
Sprayberry Sandstone	2	2	8.5 Oil	1.5 Water	28.5 Oil	40.0 Water	32.5 Oil	12.5 Water
Grayburg Limestone	13	9	4.3 Oil	1.8 Water	26.0 Oil	47.0 Water	24.6 Oil	34.1 Water
San Andres Limestone	40	25	6.5 Oil	3.1 Water	31.2 Oil	22.2 Water	27.3 Oil	13.8 Water
Clearfork Limestone	3	3	12.0 Oil	5.0 Water	93.6 Oil	90.0 Water	38.3 Oil	79.0 Water
Glorieta Limestone	1	1	0.0 Oil	0.0 Water	20.0 Oil	30.0 Water	31.0 Oil	7.0 Water
TOTALS	100	78	4.98 Oil	3.08 Water	32.32 Oil	47.15 Water	27.95 Oil	23.04 Water

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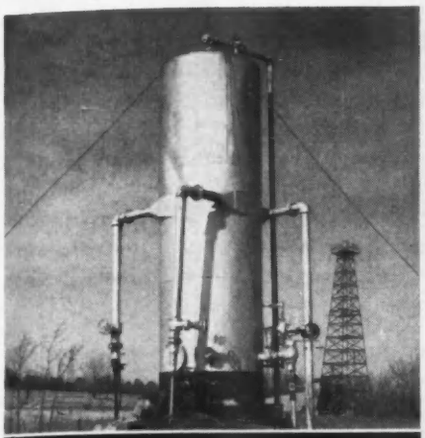

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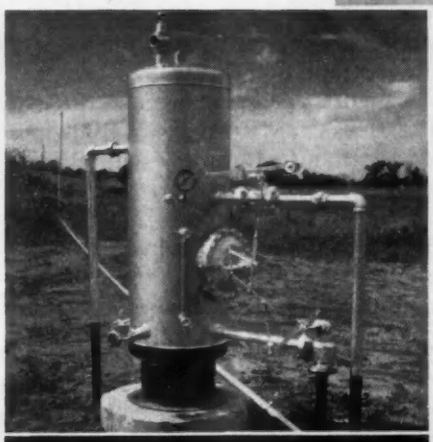

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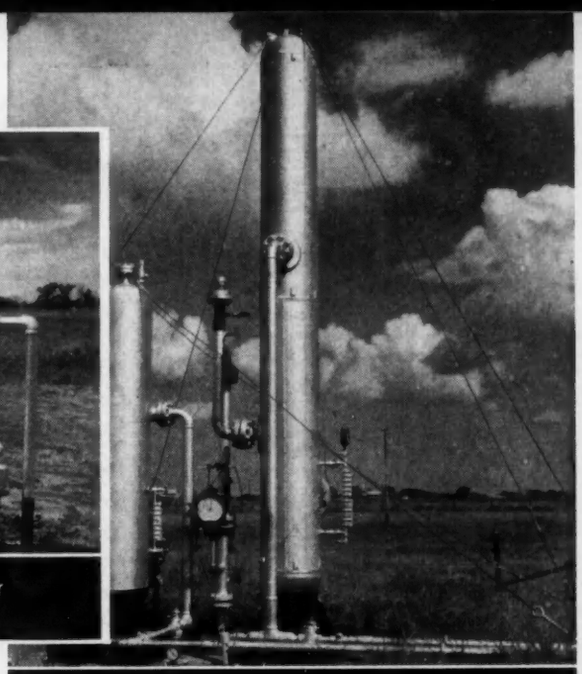

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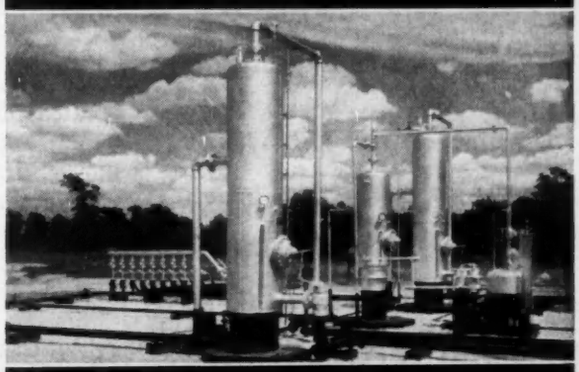

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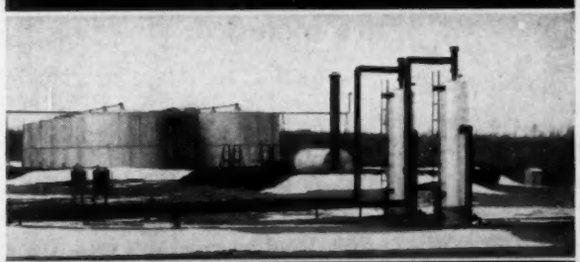

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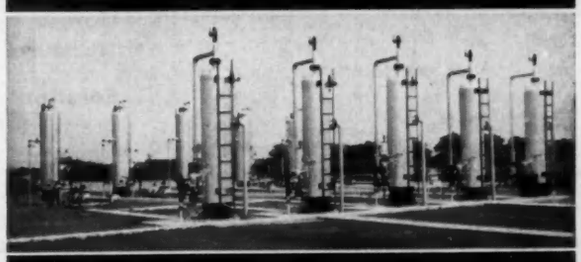

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How to determine the water content of natural gases

Determine the water content of natural gases up to 10,000 psia and at temperatures of –50° F to 300° F. Gravity and salinity corrections are included.

By John J. McKetta and Albert H. Wehe
Department of Chemical Engineering
The University of Texas, Austin

MANY INVESTIGATORS have studied the saturation water contents of natural gases at elevated pressures. In addition the dew point compositions have been determined for pure components such as methane[10], ethane[11], propane[4], butane,[12] and others.

In Figure 1 is shown a general chart for the water content of various natural gases. This chart is based essentially on the work of Dodson and Standing[2] who worked with a natural gas with a gravity of 0.65. The chart shown in Figure 1 has been corrected to a gravity of 0.60. The extension to low temperatures was taken from the work of McCarthy, Boyd and Reid[7], who used the low temperature experimental work of Skinner.[13] On the chart in Figure 1, additional data were used from the work of Deaton and Frost[1], Hammerschmidt[3], Laulhere and Briscoe[6], and others.

Hydrate formation region. The dotted line on Figure 1 shows the hydrate formation conditions. The equilibrium at temperatures below the hydrate formation temperatures is between the gas and solid hydrate rather than the equilibrium between the gas and liquid which exists at temperatures above the hydrate formation conditions. The first to point out this discrepancy were Kobayashi and Katz.[5] There is a slight change in slope of the lines below the hydrate formation temperature, however, it is hardly noticeable.

Correction for different gravity. McKetta and Katz[9] working with the methane-butane-water system showed that the amount of water required to saturate a gas depends on the molecular weight (hence the gravity) of the gas. They were able to vary the composition of their gas mixtures so they could approximate gas gravities ranging from 0.58 to 1.9. They also incorporated the results of the methane-water system[10], ethane-water system[11] and butane-water system[12] to increase the range of gravities from 0.55 to 2.0. They showed that a correction factor for gas gravity was a function of the temperature of the gas. This correction factor is shown on Figure 1 under the title "Correction for Gas Gravity" and is called, C_G where:

$$C_G = \frac{\text{lbs. water in Gas of Gravity, G}}{\text{lbs. water in Gas of Gravity of 0.6}}$$

Correction for salinity. Dodson and Standing[2] published extensive data on natural gas-water and natural gas-brine systems. They used brines of different concentrations and were able to determine the effect of salinity on the dew point compositions of the gas. McKetta and Katz[8] also presented a correction for the salinity of the brine on the dew point compositions of the natural gas-water systems.

In Figure 1 there is a "correction chart for salinity" from which the salinity correction factor, C_S, is obtained.

$$C_S = \frac{\text{lb. water in gas if gas had been in contact with brine}}{\text{lb. water in gas if gas had been in contact with water}}$$

Sample Calculation. A natural gas, Gravity = 0.9 is in contact with brine in a reservoir. The brine contains 30,000 ppm solids (approximately 3 percent NaCl). The pressure of the gas is 3000 psia and the gas temperature is 150° F. How much water is in the gas in pounds of water per million cubic feet of gas (measured at 60° F. and 14.7 psia)?

Solution: (a) Follow dashed lines on Figure 1. From the general chart of Figure 1, at 3000 psia and 150° F. a 0.6 gravity gas would contain 105 pounds of water per million cubic feet of 0.6 gas, if the gas had been in contact with pure water.

(b) Correction for gas gravity from 0.6 to 0.9: From the "correction chart for gravity," follow the dashed line from the abscissa where the desired gravity is 0.9, vertically, to the 150° F. isotherm. Read horizontally, the C_G, correction factor for gas gravity, = 0.98.

(c) Correction for Salinity of Brine: See the second correction chart on the general Figure 1. At a brine salinity of 3% go vertically to the correction line and read on the ordinate the value of $C_S = 0.93$.

Final Answer: 105 lbs. water $\times$ C_G $\times$ C_S = 105 $\times$ 0.98 $\times$ 0.93 = 95.6 lbs. water in the gas. The experimental value for this gas was 96.2 which is within the desired accuracy.

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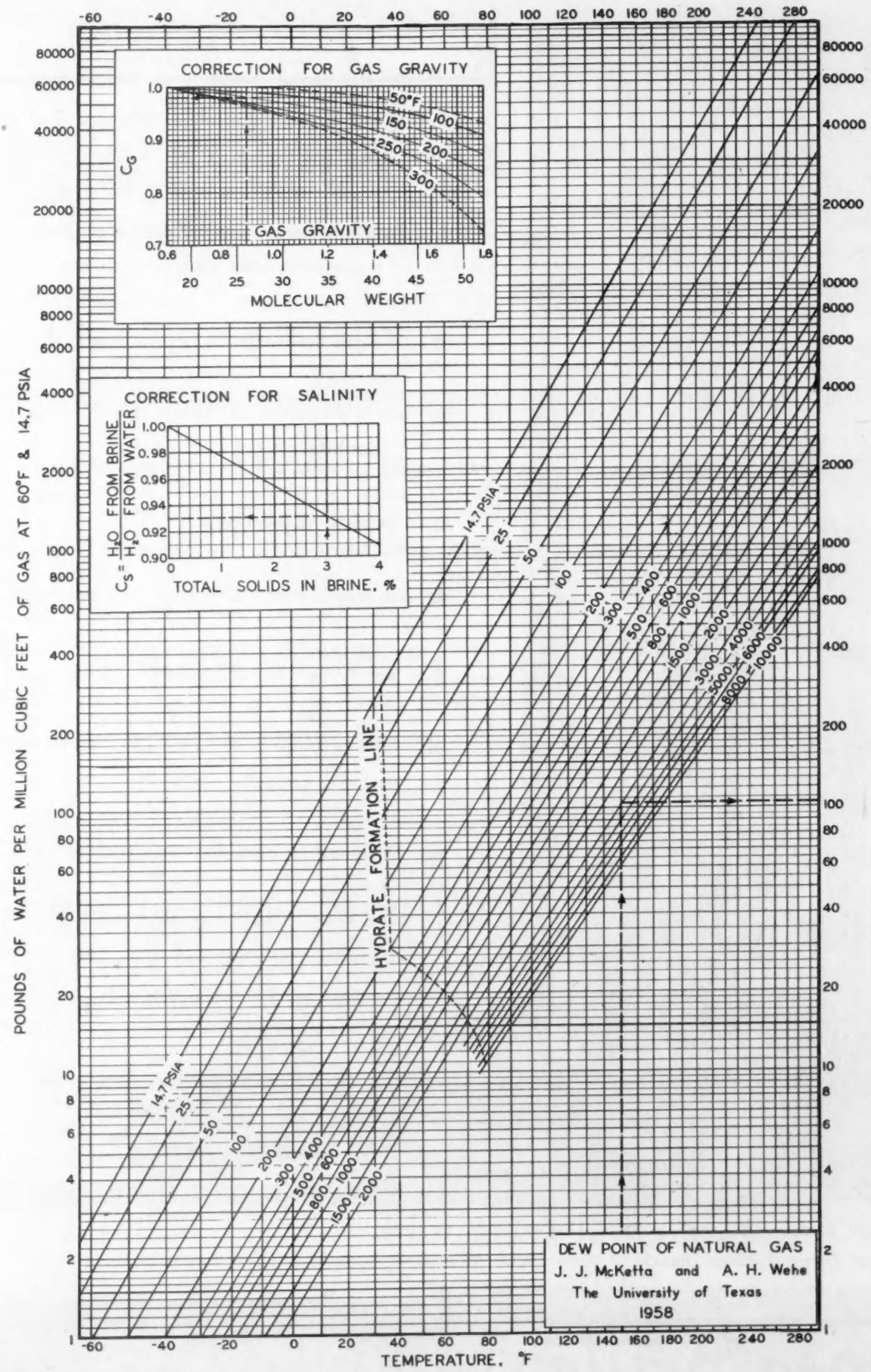
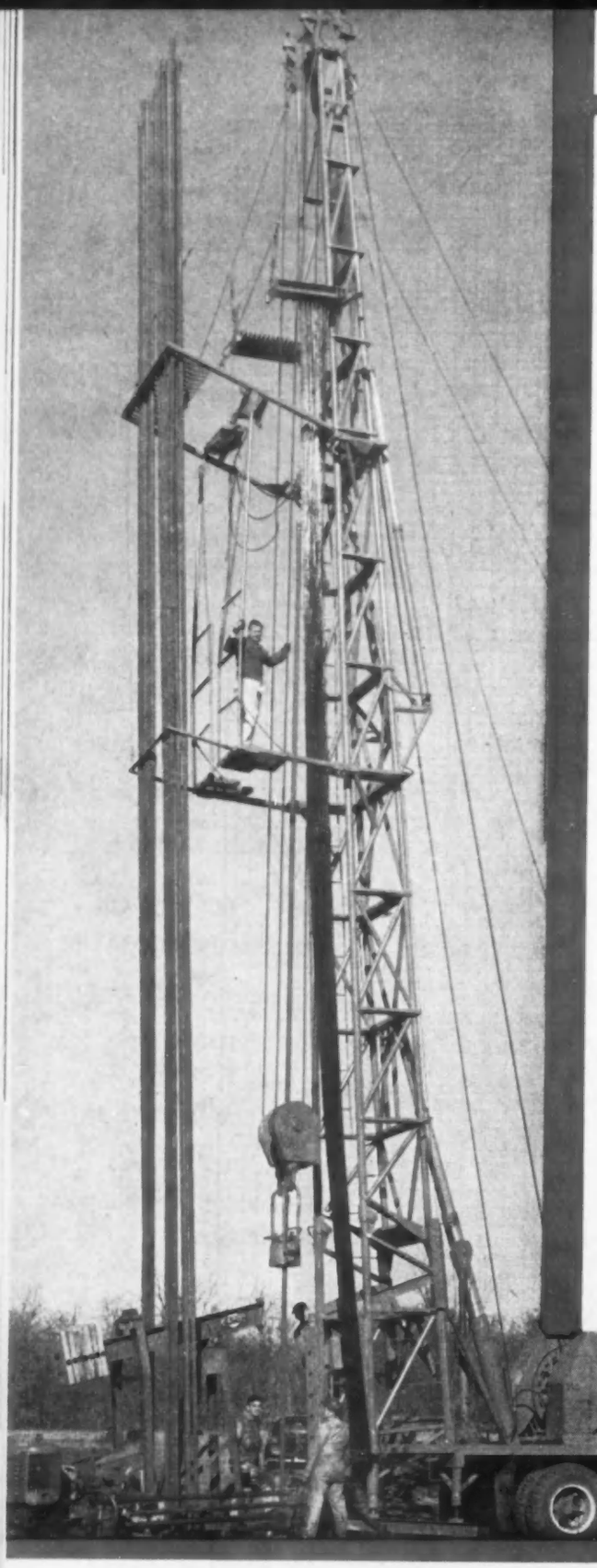


Figure 1—Water contents of natural gases with corrections for salinity and gravity.



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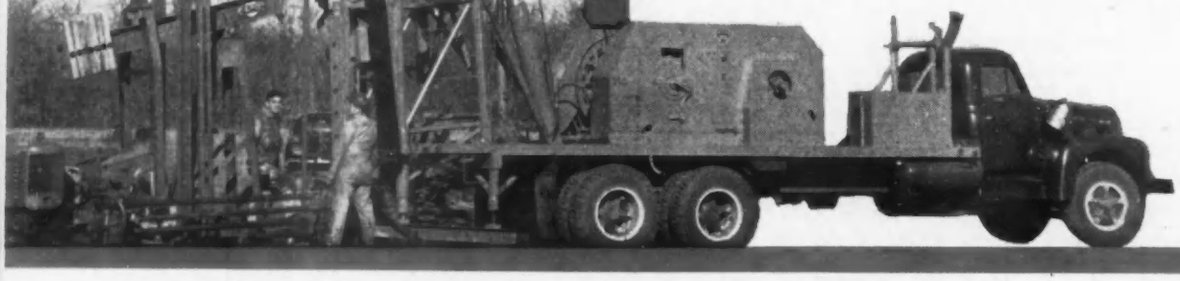

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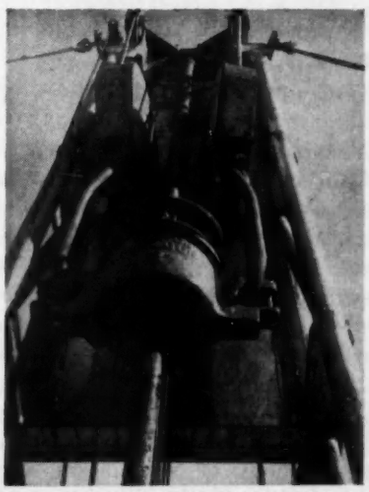
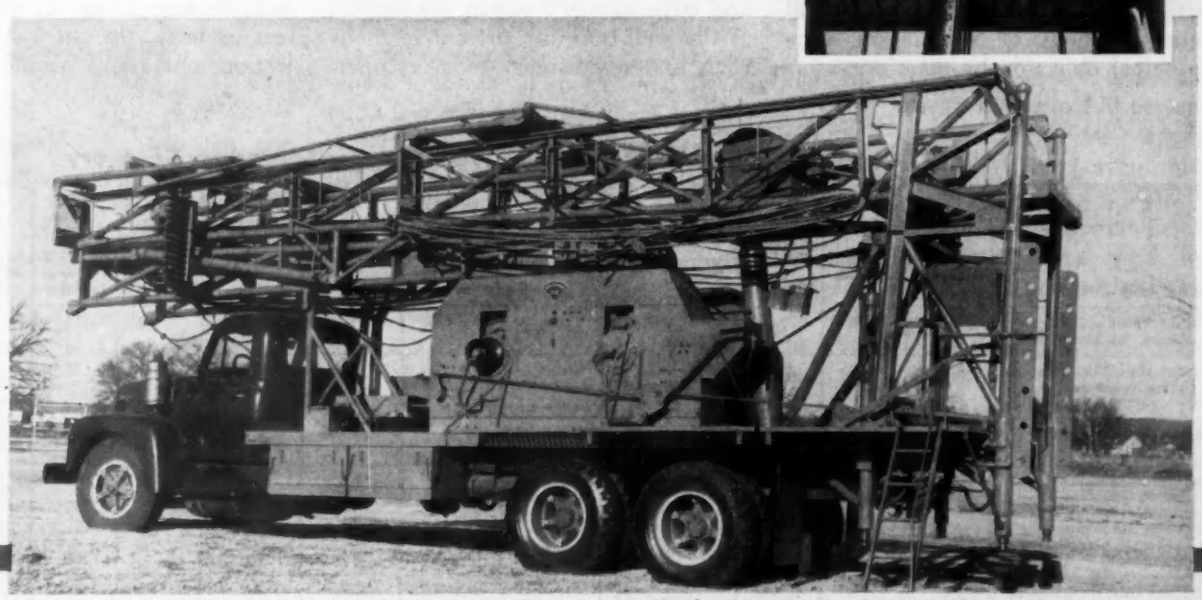
Skytop Automatic Elevators

are constructed similar to slip type elevators, except that slips are replaced by heavy dogs which engage the coupling. These dogs are manually locked in place to prevent any possibility of the elevator opening accidentally. The elevator stays on the pipe at all times.





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Survey Results Show . . .

Fracturing Can Help Secondary Recovery

Data indicates that fracturing is successful in breaking through permeability barriers at or near the well bore, resulting in an increased production or injection rate.

By Dr. E. T. Guerrero
University of Tulsa, Tulsa

EXPERIMENTAL AND THEORETICAL work in most cases has shown that fracturing, if properly controlled, is beneficial to secondary recovery operations. That is, it should result in increased production and injection rates. In spite of this, many operators have been reluctant to use hydraulic fracturing in their injection and producing wells except possibly in cases where wells failed to respond to all other methods of stimulation. The principal objection by these operators is that a long or even continuous fracture between the injection and producing wells is likely to occur, resulting in severe channeling and/or an appreciably reduced sweep efficiency. In such a case, the flood-out time would be considerably reduced but at the cost of a very low oil recovery.

Such important factors as the skin effect, low formation permeability, and large energy losses in the vicinity of the well bore are present in many wells under secondary recovery operations as well as in primary operations.

If fracturing remedies these conditions in primary operations, it should, without question, remedy them in secondary operations. In the process of improving these conditions it should be established if others, even more detrimental, are not created. It appears that if fractures could be limited in extent from the well bore (50 feet or less), the production and injection operations would be highly

TABLE 1—Some Field Results of Hydraulic Fracturing for Secondary Recovery

FIELD AND LOCATION	Depth of Formation, Ft.	Thickness of Sand, Ft.	Well Spacing or Pattern	FRACTURING SAND		Treatment Fluid Type	Amount Gals.	INITIAL PERCENT INCREASE IN		NUMBER OF WELLS TREATED		RESULTS, PERCENT SUCCESSES	
				Mesh Sizes	Lbs./ Gal.			Production Rate	Injection Rate	Production	Injection	Production Wells	Injection Wells
Various Fields in Eastern Kansas, Bartlesville sand	1879–2692	7–69	.....	20–40 10–20	½–2	Various	800–9000	—33, 1000+	—38, 1000+	35	13	85	100
Benton Field, Illinois Tar Springs sandstone	2100	10–70 Avge. 35	10 acre	20–40 10–20	0–1½ Avge. 1	Various water base gel	500–5000 Avge. 1480	.....	66, 1000+	..	26	..	96
Weber Pool Oklahoma Bartlesville sand	1200	6–72	10 acre 5 spot	....	2	Oil	100–10,000	0, 1000	.....	24	..	88	....
Bartlesville Sand Pools, Eastern Oklahoma	....	....	10 acre 5 spot	....	2	Lease Crude	3000	170, 350	.....	7	..	100	....
Hull-Silk Gas Repressuring Project, N. Central Texas, Strawn sand	....	....	.....	....	1	Oil Frac.	4000–6000	192	.....	5	..	100	....
Burbank Sand Pool, Eastern Oklahoma	....	....	10 acre 5 spot	....	2–3½	Crude and special blend oil	1500–8000	100+	.....	8	..	88	....
Bartlesville Sand Pools Eastern Kansas	....	....	10-20 acre 5 spot	....	2	Gelled kerosine Gelled lease crude	2500–10,000	370, 925	300	4	2	100	100
Langston-Kleinar Young Co., Texas, Strawn sand	3550	40	.....	....	1	Fracture Oil	700–6000	.....	.....	17	7	..	....
Various Oklahoma water flood projects, Bartlesville sand	1500–6000	28–85	.....	....	1½–2	Oil	1000–3000	33, 1000+	.....	12	..	83	....
	....	....	.....	....	....	.....	.....	.....	.....	112	48	..	....

improved and the sweep efficiency and channeling effects not noticeably changed. Whether or not fractures can be controlled to the extent desired is another controversial matter. However, it is generally agreed that the amount of fracturing material used bears an important effect on the extent and retention of the fractures obtained.

From these considerations, it is possible to list many of the probable advantages and disadvantages of hydraulic fracturing for secondary recovery operations.

Possible Advantages

1. Increased injection rates for a constant injection pressure or reduced injection pressures for a constant injection rate.

2. Reduced flood out time.

3. Increased production rate by reducing the skin effect and increasing the area for drainage in the vicinity of the producing wells.

4. Faster pay-out due to the reduced flood out time and lower operation costs.

Possible Disadvantages

1. Creation or aggravation of channeling resulting in the early breakthrough of the flooding fluid, by-passing the oil and giving a lower sweep efficiency and subsequent lower recovery.

2. Slow pay-out due to the low recovery and cost of the treatment.

Another important consideration is the matter of stratification. It is an accepted fact that most producing formations contain large variations in permeability in a plane perpendicular to the bedding and to some unknown degree also parallel to the bedding. This means layers of different permeabilities are superimposed on each other with variations of permeability laterally within a layer. Thus, it would appear that the best results could be obtained if only the lower permeability portions were fractured. This would tend to equalize the flood-out time of these portions with those of higher permeability and thus result in a higher recovery. Fractures in the higher permeability portions would tend to aggravate channeling and by-passing. It is readily seen that for most cases of this type, horizontal fractures would be preferred over any other type. Vertical or random fractures would also affect the high permeability portions. Of course, the thickness and range of permeabilities between the various portions would also be important factors.

Field Experience. The numerous factors involved in the theoretical evaluation of fracturing in secondary recovery operations make it impossible to fully determine the advisability of its use under many sets of conditions. Consequently, it is necessary to critically review those fields and formations where fracturing has been utilized (in secondary recovery operations) to see if field experience will verify suspected behavior.

In Table 1, field results of hydraulic fracturing for secondary recovery are shown. The fields are located primarily in the Mid-Continent area, Illinois and North Central Texas. Formations included are the Tar Spring Sand (Illinois), Bartlesville Sand (Oklahoma), Strawn Sand (Texas) and the Burbank Sand (Oklahoma).

Formation depths and thicknesses, where reported, ranged from 1200 to 6000 feet and four to 85 feet, respectively. The fields involved, for the most part, had 10-acre well spacings and used five spot flooding patterns. Note that the type of fracturing fluids used included most of the types available. An oil-base type was used for a large portion of the treatments in producing wells and a water-base type in the injection wells. The size of the fracturing treatments ranged from 100 to 10,000 gallons. Generally sand was used in most treatments ranging in amounts from up to three pounds per gallon with an average of about 1½ pounds per gallon.

Success of the fracturing treatments reported in Table 1 is shown as the initial percent increase in production and injection rates on wells in which pay-out and profit were realized. The initial percent increases in production ranged from negative values (production rate less after fracturing) to 1000 plus percent. These initial percent increases only indicate the initial reaction to fracturing and do not necessarily point out that the treatments were a success. The success of fracturing treatments will be reflected in the production of projected recovery at a higher rate or the production of additional oil above that projected. In either case the additional recovery or higher rate of recovery should result in enough additional income to pay for the treatment and result in an additional profit.

In the case of injection wells, success can be based on the ability of a treated well to take more water in the desired sand interval at the same pressure or the same amount of water (as before the treatment) at a lower injection pressure. In either case the economics should be such that the treatment will pay-out in a reasonable amount of time with some profit realized. Note in Table 1 that the initial percent increase in injection rates ranged from negative values (lower injection rates after treatment) to 1000 plus percent. Failures in the case of injection wells would almost have to be due to one or both of two reasons.

1. Creation of fractures at undesired intervals.

2. Creation of negligible or insignificant fractures. This reasoning assumes that large fractures (tending to intercommunicate production and injection wells) are not created. Note that for production wells, the success range is from about 80 to 100 percent with an average of 85 to 90 percent. For injection wells, the percent success range is higher, 95 to 100 percent.

Certainly the number of fields, formations and individual wells involved in Table 1 are far too few to afford conclusive results; however, interesting and significant trends are indicated. It is probably true that enough fracturing for secondary recovery operations has been performed to afford more conclusive results. However, in most cases the results have not been reported. For instance, an authority on secondary recovery operations informed the writer that he had experience with some 37 water-floods ranging in depth from 800 to 3000 feet in an area extending from the Mid-Continent to West Texas. Of 37 water floods, fracture treatments had been performed on 23. One of the 23 water-floods is not included in the final analysis because this fracturing involving 50 wells,

took place during primary operations. Observations thus far indicate this flood will be successful. In the remaining 22 water-floods, 227 production wells were fractured. Twenty-four of these wells could not be evaluated because their production was on the upgrade at the time of fracturing. Of the remaining 203 wells, 187 (92 percent) were considered successes. Fracture treatments resulted in an estimated recovery of 1,344,000 barrels of oil or an average of 7200 barrels of oil per well. This has occurred over an average period of three years prior to November, 1956. The other 16 wells were considered failures. Their increased recovery due to fracturing amounted to less than 1500-2000 barrels per well. Cost of the fracture treatments ranged from $700 to $2,000 and the average pay-out time for successful treatments was 30 to 90 days. In these same floods, 21 injection wells were fractured with 100 percent success. These data are summarized in Table 2.

TABLE 2—Results of Hydraulic Fracturing in Water Flooding Operations

Total Number of water floods involved	37
Depth Range	800 to 3000 ft.
Areas Included	Mid-Continent to W. Texas
Number in which Fracture Treatments were performed	23
Number involved in final analysis (The other flood has 50 wells fractured during primary operations)	22
Number of producing wells fractured (24 of these had rising production rates during time of fracturing. Of remaining 203, 187 were considered successes.)	227
Percent successes, producing wells	92 percent
Increased production due to fracturing, over three-year period to November, 1956 (Average of 7200 bbls. oil per well)	1,340,000 bbls.
Number of injection wells fractured (100 percent successful)	21
Range of cost per fracture treatment	$700 to $2000
Average pay out time	30 to 90 days

The high degree of fracturing success in these 23 floods was due primarily to the good and rather complete engineering data available on more than 95 percent of the wells. These data consisted of well completion information, logs, core analyses and individual well production histories. It is believed that in most wells fracturing was a corrective measure. That is, fracturing broke through scale deposition (from a few inches to several feet) at or near the well bore or througgh other types of skin effects. The availability of good engineering data would make it possible to more accurately select those wells most likely to benefit from fracturing treatments.

The writer consulted with major company, independent, consultant and service company fracturing experts concerning their opinions of fracturing for secondary recovery. These opinions are summarized in Table 3. The areas cover almost every state where secondary recovery operations are under way including the Mid-Continent, North and Central Texas, West Texas, Illinois, Ohio and the East Coast. The range of depths covered is 500 to 8000 feet with well spacings involving three to 160 acres. It is significant to note that three of the sources gave three to five acres as the lower limit of well spacings where fracturing has been successfully applied to secondary recovery operations. All types of fracturing fluids have been used in amounts of 500 to 10,000 gallons with from 0 to three pounds per gallon of sand.

Perhaps the most interesting experts' opinion concerning the success of fracturing for secondary recovery was that 75-85 percent of the treatments are successful in producing wells and 85-100 percent successful in injection wells.

They gave two principal reasons for failure:

1. Obtainment of fractures that extend into the overlying free gas sand or underlying bottom or edge water resulting in aggravated free gas and/or water production
2. Not being able to place fracture where desired due to bad cement job, incorrect placement of perforations or leaking packer.

Conclusions. Based on field reports and expert opinion it is concluded that fracturing can be used to advantage in many secondary recovery operations. It is particularly helpful in increasing the injection or production rate by breaking through permeability barriers (skin effect) at or near the well bore. Experience over most secondary recovery areas of the country indicates that about 80 percent of the producing wells fractured have an improved recovery and a reasonable pay-out time, three months or less. The success with injection wells is even higher.

If good engineering data is available and correctly applied, higher success can be expected from the use of fracturing in secondary recovery operations.

TABLE 3
Some Factors and Opinions Concerning Hydraulic Fracturing for Secondary Recovery

FACTOR OR OPINION	SOURCE OF INFORMATION				
	1	2	3	4	5
Areas	Kansas Oklahoma	N. E. Oklahoma	Mid-Continent West Texas New Mexico	Kansas, Illinois, N. Texas, Ohio, W. Virginia, N. Mexico	Mid-Continent East Coast (Bradford) N. & Central Texas
Types of Wells Treated	Production & Injection	Mostly Production	Production & Injection	Production & Injection	Production & Injection
Range of Depths, ft.	1000–6000	1250–2500	500–6500	500–8000	1500–4000
Well Spacing Involved, Acres	5–80	10–40	3–160	5–80	10–40
Types of Fracturing Fluids Used	Various, Oil to water	Mostly oil, some salt water	Oil Gelled lse. crude, gelled water	Almost every thing, fresh water, salt water, gel oil	Gelled water, oil lease crude
Amount of Fracturing Fluid Used Fluid, gal.	1000–6000	3000–5000	500–6000	250–10,000 (Avge. 4000)	500–5000
Sand, Lbs./gal.	1–2	2	1–2	0–3	Avge. 1
Results, Percent Success Injection Wells	90+	.....	95–100	90	85
Production Wells	80+	80	80–85	75	75

Summary Explanation of Failures:
1. Obtainment of vertical type fractures that extend into overlying free gas portions of sand and into underlying bottom water result in aggravated free gas or water production.
2. Inability to place fracture where desired due to bad cement job, incorrect placement of perforations or leaking packer.

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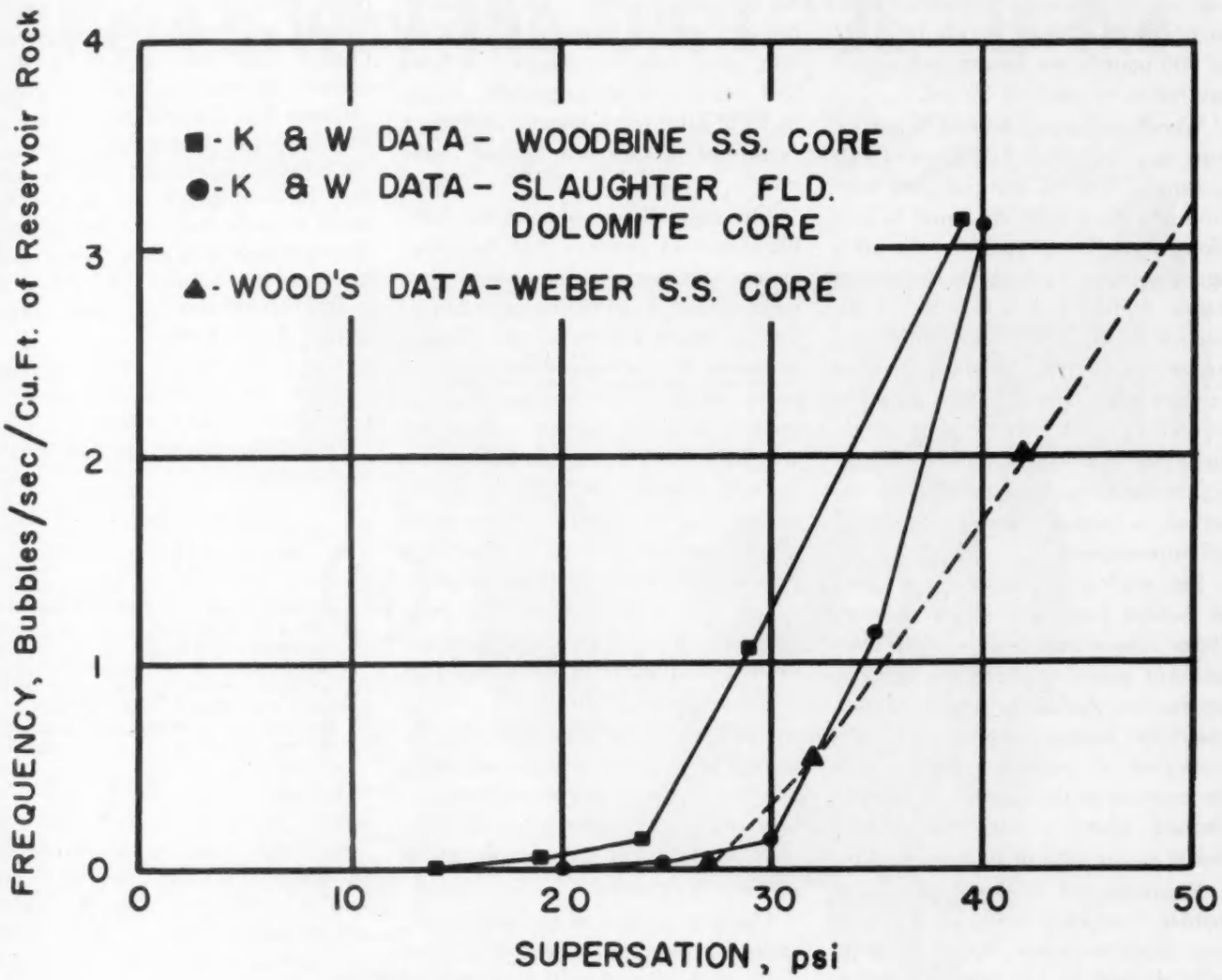

FIGURE 1—Average bubble frequency curves.

Does Bubble Formation Affect Reservoir Performance?

Experimental laboratory data show that the degree of bubble formation substantially modifies the oil recovery in gas-drive fields.

By Denton R. Wieland,
Petroleum Engineering Department
A. and M. College of Texas
College Station, Texas

THE SIGNIFICANCE of bubble formation in reservoirs is that their number determines the departure from equilibrium in the reservoir and may modify substantially the K_g/K_o ratio and thus the oil recovery in gas-drive fields. Unfortunately, no practical means is known to change the number except high production rates. The work to date has given a better understanding of the correlation of laboratory and field results.

Various authors have shown that the frequency of gas bubble formation in a liquid decreases with a decrease in supersaturation. The degree of supersaturation is defined as the pressure difference between the bubble point of a gas-saturated liquid and its pressure at a given temperature.

Kennedy and Olson[1] dealt with observations and measurements of bubble formation on calcite and quartz crystals using a mixture of methane and kerosine. They noticed that the gas bubbles formed on the surface of the crystals in preference to the body of the liquid or the glass surface. They reported the frequency of bubble formation expressed as the number of bubbles formed per second per square

centimeter of crystal surface in contact with the liquid varied from .22 at 800 pounds per square inch supersaturation to zero at 30 psi.

Wood[2] performed bubble frequency tests on a core from the Rangely Field, Colorado. The oil and gas used were from the same field. As found in previous work, he reported that the average frequency of bubble formation varied regularly as a function of supersaturation. The frequencies expressed in this case as the number of bubbles per cubic foot of rock per second ranged from .023 at 27 psi supersaturation to 68.9 at 202 psi supersaturation. No bubbles were observed to form at pressures below 27 psi supersaturation.

Stewart,[3] et al., studied the effect of bubble formation in oil recovery from limestone cores with non-uniform porosity where the primary production mechanism was a solution gas drive. They reported that the efficiency of oil recovery increases with an increase in the number of bubbles formed, which in turn was proportional to the rate of pressure decline.

Kennedy and Wieland[4] performed bubble frequency tests on dolomite and sandstone cores. Again, their results showed an increase in bubble frequency with an increase in supersaturation. The frequencies expressed as the number of bubbles per cubic foot of reservoir rock per second, varied from zero at pressures up to 19 psi supersaturation to 3.1 at 40 psi supersaturation. Figure 1 contains the frequency curves obtained by Wood and Wieland.

Bubble frequencies, and the number which may form in a reservoir under stated conditions, are of little direct interest to the reservoir engineer. Our concern in such measurements results from the fact that bubble frequencies, along with the rate of pressure decline imposed by production, determine the number of bubbles existing in the reservoir, which in turn determines several important factors of performance of the reservoir.

The most direct value of the bubble frequency curve is that the intercept of this curve on the pressure axis determines the minimum supersaturation at which a bubble was observed to occur. It is not established that, at pressures below this intercept, the frequency is absolutely zero since this would require that no bubbles be formed in an infinite period of observation. It is known that in one series of tests no bubbles were observed in a period at 30 psi supersaturation which would have allowed over 2000 bubbles to be formed at 40 psi supersaturation and over 10,000 bubbles at 50 psi supersaturation.

With the above limitation, the intercept on the bubble frequency curve determines the degree of supersaturation which must exist before bubbles start to form in a reservoir as its pressure is depleted.

Using the slopes of the bubble frequency curves just above the intercepts, it is seen that the number of bubbles forming, per cubic foot of rock per day, for a reservoir supersaturated to the extent of only one psi above the intercepts, for the different measurements reported in the literature, would be as shown in Table I. Because of uncertainties in the values of both the intercepts and the slopes, the data are calculated only in orders of magnitude.

It is seen from Table 1 that the number of bubbles formed after one day of supersaturation one psi in excess of the intercept value is very much lower for natural cores and fluids than for the kerosine—crystal systems reported by Kennedy and Olson.[1] This may be due to differences in the nature of the pure crystal surfaces and natural rock grains, to lower specific surfaces for natural rocks than those assumed, or to variation in fluid properties. It is of interest to determine the effect this wide divergence of frequency values would have on the number of bubbles actually formed during pressure depletion of the reservoir.

Using the steady state diffusion equation for steady state flow, it has been shown[1] that the flow of gas into each bubble may be approximated by the equation.

$$Q = \frac{3.2\pi D (S_e - S_b)}{\frac{1}{r_b} - \frac{1}{r_e}}$$

Where D is the diffusion constant of the gas in the oil S_b and S_e are the concentrations of gas, respectively, at the surface of the bubble and at the extreme radius of the sphere of influence of the bubble.
r_b and r_e are respectively, the radius of the bubble and of the sphere of influence.

If the lowest total number of bubbles tabulated in Table 1 for one day's time at a supersaturation one psi greater than the intercept is used, and it is assumed that the bubbles are initially one mm in radius, it may be calculated that the bubble will reach five mm in radius in less than one hour. At five mm radius, the number of bubbles tabulated in Table 1 indicate that in excess of one percent of the pore space would be filled with gas in less than one day's time. This rate is impossible, because at normal production rates the space voided would be negligible compared to it. What this rough calculation indicates is that even at the lowest frequency rate tabulated, the supersaturation existing is still determined by the intercept of the frequency curve and not by its initial slope. Within the accuracy of our method of calculation, we may conclude that the upper limits of supersaturation existing in reservoirs are the intercepts as listed in Table 1. Average values, which would be important in material balance calculations and other performance estimations, would be substantially lower than the maximum values calculated.

Olson showed that the cumulative

TABLE 1—Calculated bubbles formed per cubic foot of rock per day, at supersaturations one psi above intercept.

Reference	Oil	Core	Intercept psi	Slope of Curve Near Intercept Bubbles/psi/ Second/Cu. Ft.	Bubbles, No./Cu. Ft/Day
(1)	Kerosene	Crystals	30	18.2*	10^8
(2)	Rangely	Rangely	27	.154	10^4
(4)	East Texas	Woodbine	14	.01	10^3
(4)	East Texas	San Andres	15	.01	10^3
(4)	Slaughter	San Andres	20	.005	$.5x10^3$

* Assuming 450 cm.^{2} surface area per cm.^{3} of rock.

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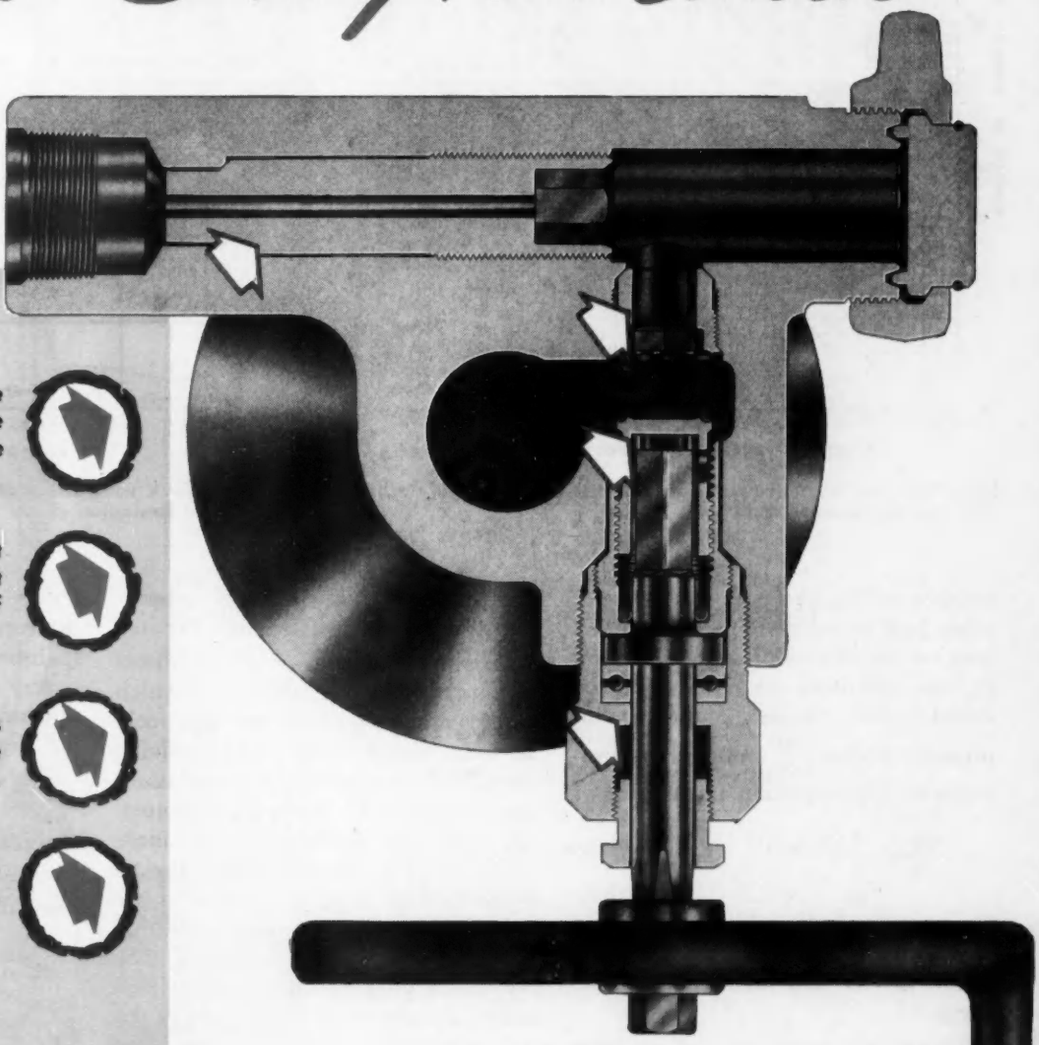

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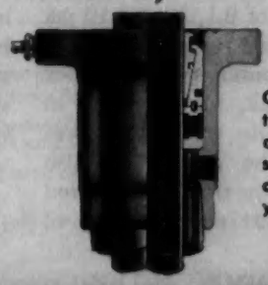

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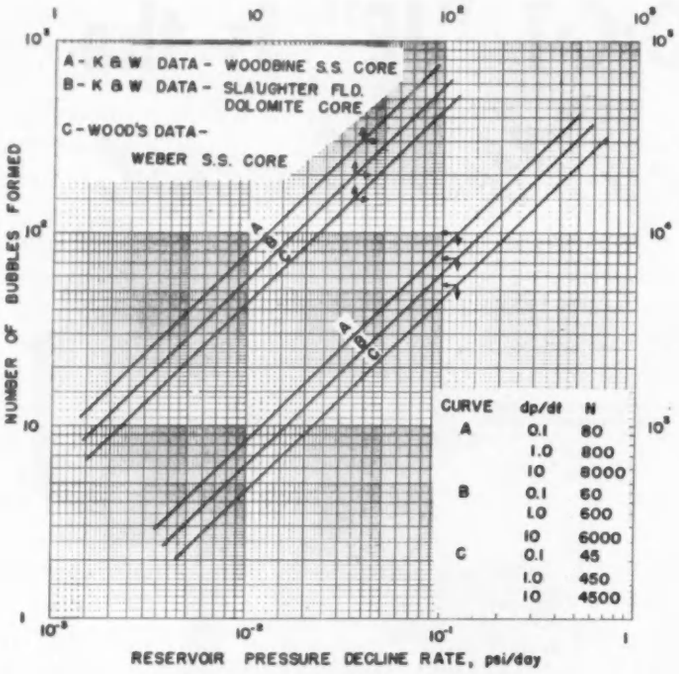
A - K & W DATA - WOODBINE S.S. CORE
B - K & W DATA - SLAUGHTER FLD. DOLOMITE CORE
C - WOOD'S DATA - WEBER S.S. CORE
NUMBER OF BUBBLES FORMED
RESERVOIR PRESSURE DECLINE RATE, psi/day
CURVE dp/dt N
A 0.1 80
1.0 800
10 8000
B 0.1 60
1.0 600
10 6000
C 0.1 45
1.0 450
10 4500

FIGURE 2—Calculated relationship between pressure decline rate and the number of bubbles formed.

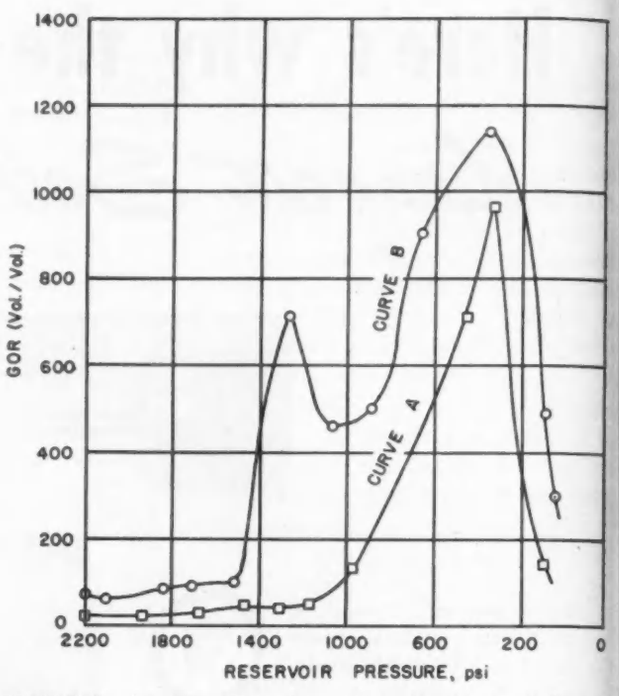

FIGURE 3—A comparison of gas-oil ratio curves to show the effect of the formation of gas masses.

number of bubbles (N) formed per cubic foot of reservoir rock depended only on the degree of supersaturation P_s, the diffusion constant D, the initial bubble radius r_b, the rate of pressure decline $\frac{dp}{dt}$ imposed by production. The equation is as follows:

$$\frac{dp}{dt} = \frac{3.2\pi P_s ND}{\frac{1}{r_b} - \frac{3}{\sqrt{4.2N}}}$$

For pressure declines in a hypothetical rock of 0.1, 1 and 10 psi per day there would be 40, 400 and 4000 bubbles formed.

Using this equation and applying Wieland's data, the curves on Figure 2 were obtained. For pressure declines of 0.1, 1 and 10 psi per day the value obtained for the number of bubbles formed per cubic foot of rock was 80, 800 and 8000 for the sandstone core and 60, 600 and 6000 for a dolomite core. Wood's data gave 45, 450 and 4500 bubbles per cubic foot of reservoir rock for the same pressure declines.

Stewart,[3] et. al., using different assumptions, calculated that for pressure decline rates of 0.1, 1, and 10 psi per day there would be a total of 10, 100, and 1000 bubbles formed per cubic foot of rock, which agree in order of magnitude with those previously noted. The results are also in agreement with the others cited that the cumulative number of bubbles formed is directly proportioned to the rate of pressure decline.

It is of interest to observe a direct conformation of the manner in which gas masses may move through rock. In some unpublished data[5] involving gas-oil rates measurements in solution-gas-drive runs, 65 curves were plotted. Of these, 38 showed one or more large jumps in gas-oil ratio, followed by returns to normal values. Typical behavior for normal and abnormal curves are shown in Figure 3. The 38 curves showing abnormalities represent average production rates of 0.5 ccs per minute while the normal curves averaged 0.71 cc. per minute. It is seen that the slower rate of pressure decline favored fewer bubbles and larger masses of gas when they reached the well. The tests differed from runs usually made in that precautions were taken to eliminate initial gas bubbles by subjecting the system to prolonged pressures several hundred psi above the bubble point.

It has been noted[1] that different relative permeability curves would be expected for identical rocks and fluids in which a different number of bubbles have been generated by different pressure histories. Stewart,[3] et. al., have shown that this is of great importance in non-homogeneous limestone rocks, where many pores contain oil but do not act as carriers for it. These authors have measured relative permeability ratios of gas to oil at different pressure decline rates, and have established the fact that increases in recovery in excess of 10 percent can be attributed to the greater number of bubbles formed at high pressure decline rates.

It is further pointed out by these authors that laboratory data, necessarily associated with faster decline rates than occur in reservoirs, should not be used to predict full scale results. In the limestone cores investigated, they suggest that displacement by injected gas gives a lower recovery in the laboratory than the solution-gas-drive process and duplicates more closely results obtained in the reservoir.

ACKNOWLEDGMENT

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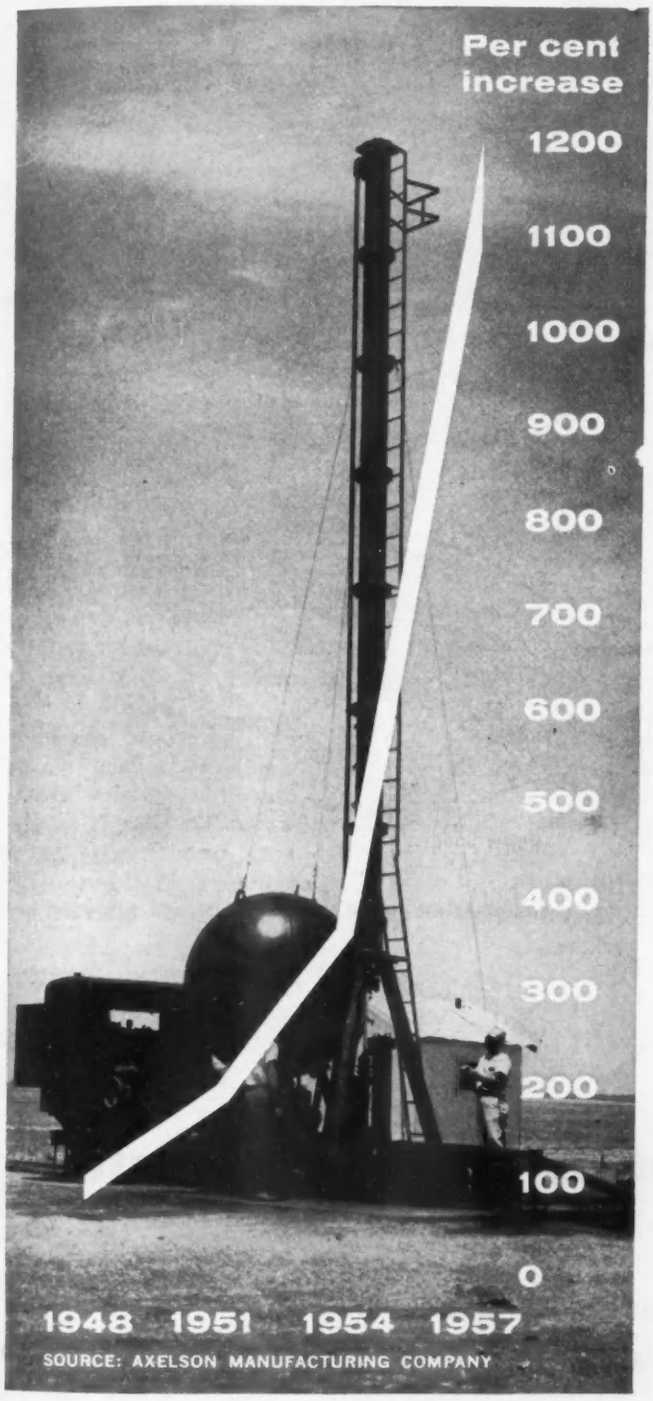

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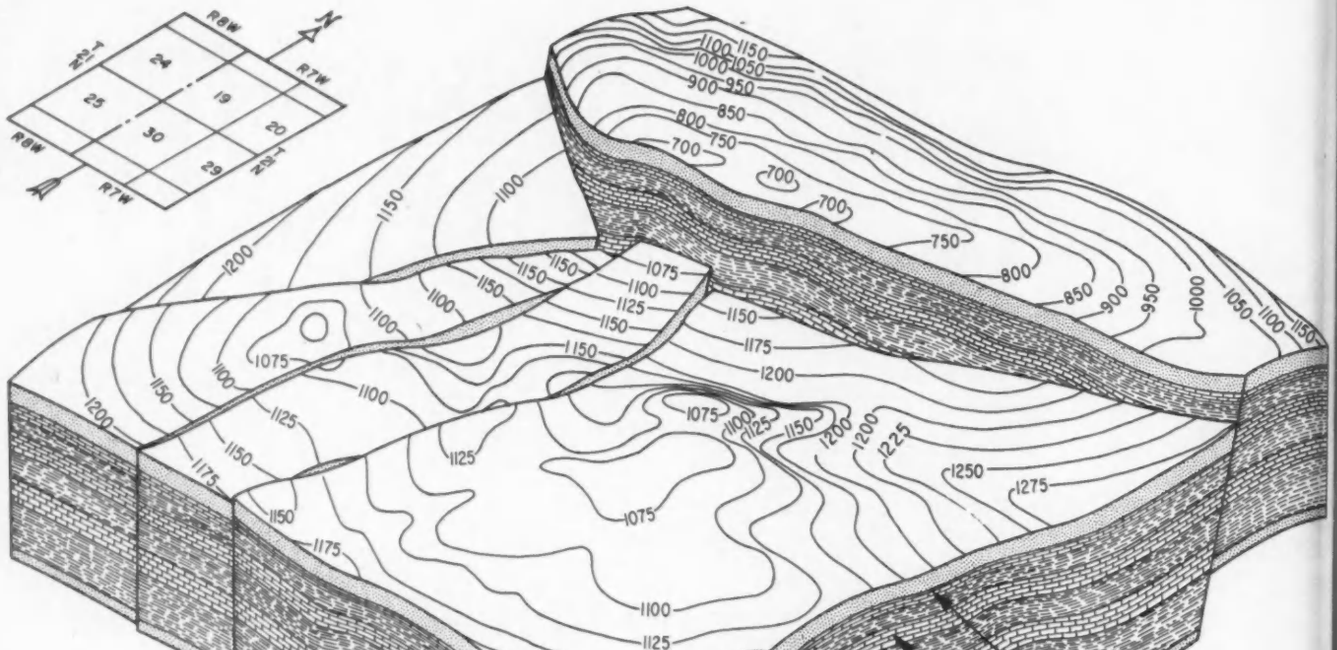

FIGURE 1—Isometric projection of the Homer field. Subsurface structure contours on the top of the Nacatoch sand below sea level.

In North Homer Field, Louisiana . . .

Gas repressuring methods prove successful

Ultimate recovery estimated at 63 million barrels, or 61 percent of the initial oil in place.

By Paul R. Waddle
Consulting Petroleum Engineer, Shreveport

OIL PRODUCTION from the North Homer Nacatoch sand reservoir, Claiborne Parish, Louisiana, is due in large part to gas repressuring. Discovered in 1919, the field has been under gas repressuring since 1934 as a supplement to the primary solution gas drive and gravity drainage producing mechanisms. As of Jan. 1, 1958, the field accumulated oil recovery amounted to 52.5 million barrels, or about 51 percent of the original oil in place. Of this total recovery, 6.3 million barrels, or 12 percent is credited to repressuring. Current oil production averages about 1,500 barrels per day, of which 500 barrels per day, or 33 percent is attributed to repressuring. Ultimate oil recovery under the present operating program is estimated to be 63 million barrels, representing 61 percent of the original oil in place.

Geology and reservoir characteristics. The field is part of a dome having a diameter of approximately 9 miles. The dome is cut by an east-west trending fault that is downthrown to the south. The vertical dis-

Effective Nacatoch pay thickness averages about 55 feet

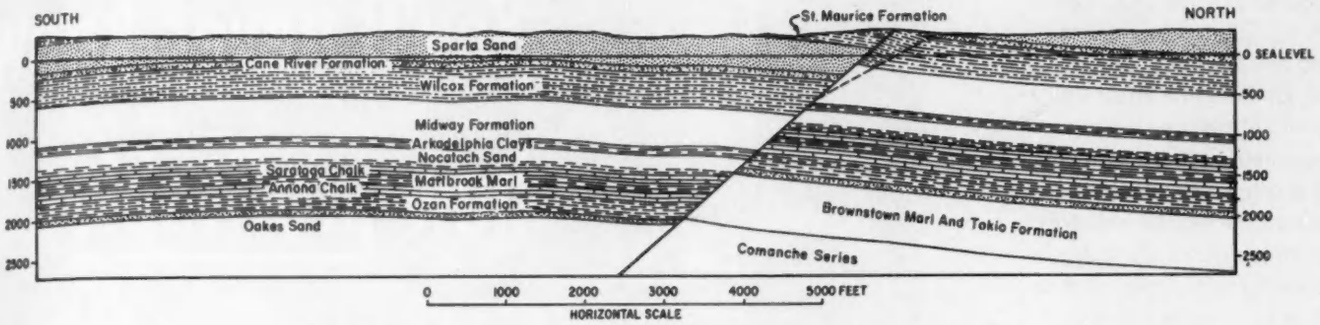

FIGURE 2—Cross-section of the Homer field. Depth shown in feet.

placement of the fault, from 300 to 500 feet, is sufficient throughout its length to prevent transmission of fluid across it, thus sealing off the 100 to 120 feet of gross productive section of the Nacatoch sand to the north to form the reservoir (see Figures 1 and 2, taken from Structure of Typical American Oil Fields, Volume II, 1929, by W. C. Spooner).

The top of the producing formation is found at 925 feet (675 feet subsea) near the fault and dips at a constant rate of 500 feet per mile to the water-oil contact at a depth of 1,350 feet (1,115 feet subsea) on the flanks. Figure 3 is a structure map contoured on top of the Nacatoch sand. Productive area is about 1,300 acres. The effective pay thickness averages about 55 feet being thicker upstructure near the fault. The producing section, a fine-grained sand, is interbedded with shale and chalk streaks. Porosity is about 33 percent while permeability averages some 200 millidarcys. Average connate water saturation is estimated at 40 percent of pore volume based on capillary pressure tests of core samples. Water underlies only the flank leases.

PRODUCTION HISTORY

Early stages. The discovery well, Lowenberg 1, was drilled by Standard Oil Company of Louisiana, in June 1919. It produced 150 barrels of oil per day from the Nacatoch sand at a depth of 1,160 feet. The high price of oil, which averaged more than $3 per barrel during 1920, stimulated rapid development of the field. High producing rates and lack of pipe line and storage facilities made accurate well tests difficult, but it has been estimated that many of the wells had capacities of from 4,000 to 12,000 barrels per day. In the early stages of production it was the practice of many of the operators to penetrate the formation only a few feet and

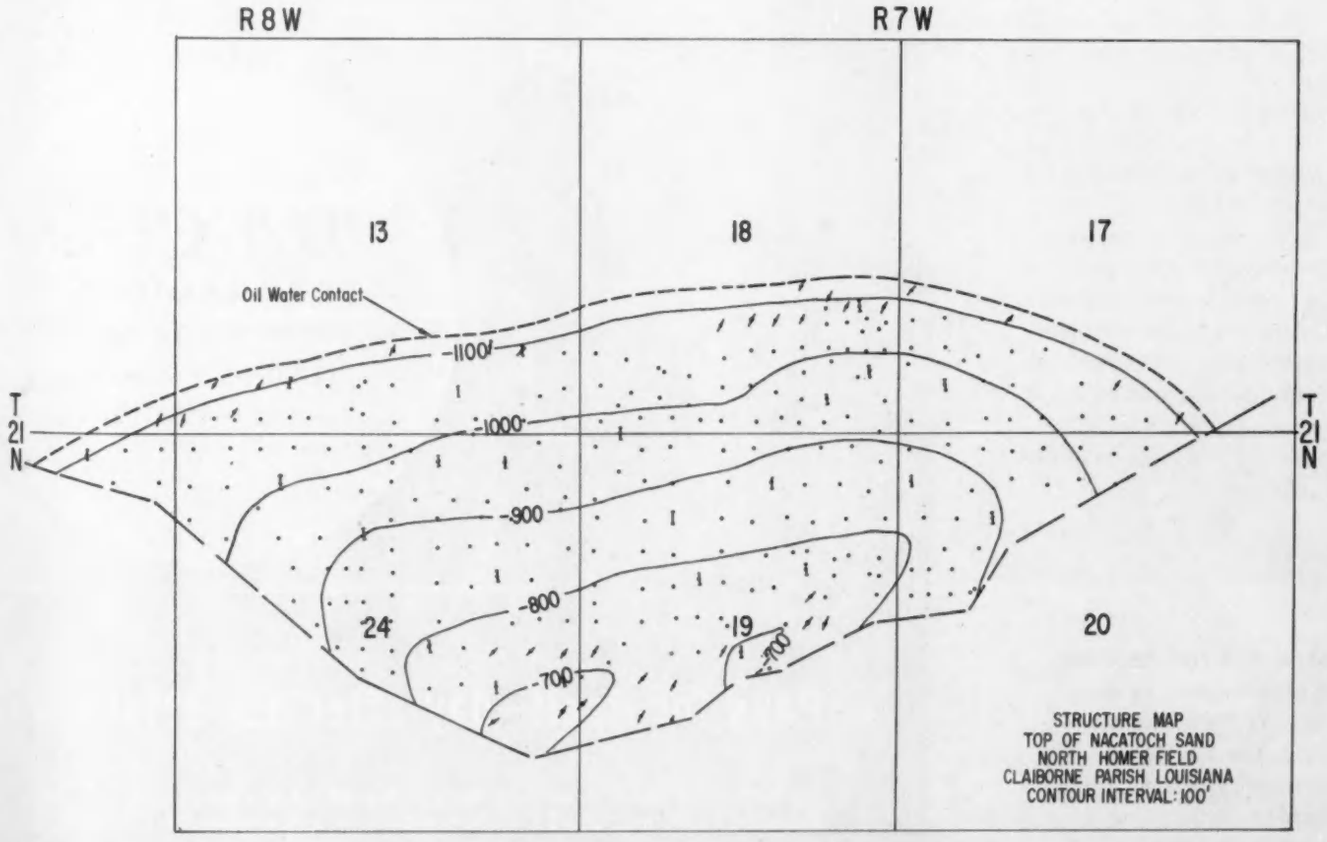

FIGURE 3—A structure map contoured on top of the Nacatoch Sand is shown. The productive area is approximately 1,300 acres. The producing section is a fine-grained sand with shale and chalk streaks. Permeability averages about 200 md.

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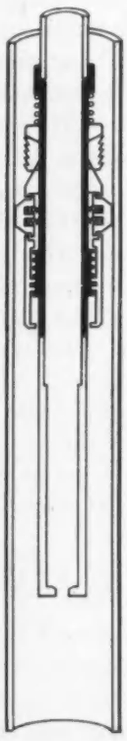
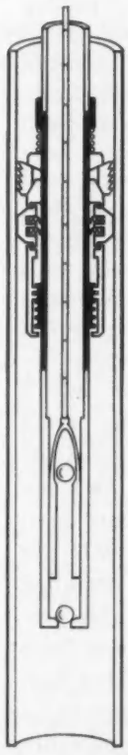
A

Tubing run-in, Anchor not engaged



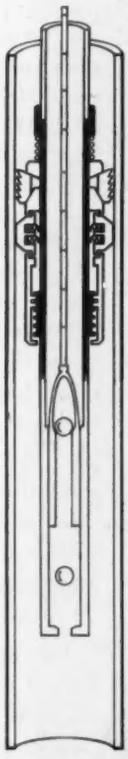
B

Pump in place, Anchor engaged. Tubing stretches with down-stroke of pump. Anchor is moved downward.



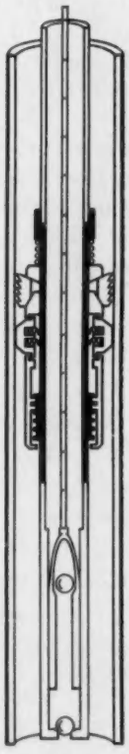
C

Up-stroke does NOT move Anchor or tubing. Succeeding down-strokes move Anchor downward until . . .



D

Maximum elongation due to increasing fluid load has occurred. Tubing is in proper tension to eliminate both breathing and buckling



WHAT DOES COMPENSATING MEAN?

"COMPENSATING" means that the tubing is allowed to adjust itself to compensate for any changing well condition that requires additional tension in the producing string. The above illustrations show how the Anchor is adjusted downward by one factor (in this case the increasing fluid load in the tubing) causing tubing elongation. Any other factor (temperature rise, annulus decline, etc.) requiring an increase in tubing tension, is automatically compensated for in a similar manner.

HOW DOES IT WORK?

In order for a tubing anchor to accomplish complete elimination of both breathing and buckling, it is necessary for it to be so designed and constructed that it will continually catch and maintain the tubing at the lowermost point in its downward travel during each adjustment. Only in this manner can the exact amount of tension required be kept in the tubing string at all times . . . and only Baker Compensating Anchors have this feature, as illustrated in the drawings below.

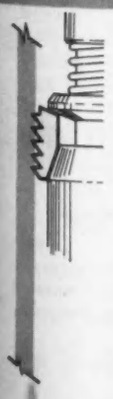


Fig. E

Slips of Anchor engaged in I.D. of casing, maintaining tension in tubing.

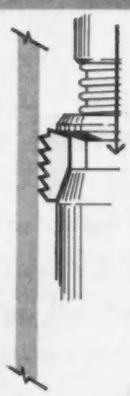


Fig. F

As tubing elongates, Slips momentarily disengage sufficiently to allow tubing to move downward.

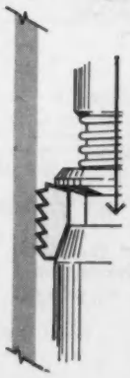


Fig. G

Anchor being moved down casing by tubing elongation. Note that Follow-Up Spring maintains contact between Cone and Slips, keeping Slips against casing so that . . .

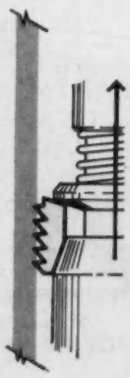


Fig. H

When tubing tries to reverse its direction and move upward, Slips are **immediately re-engaged,** maintaining proper tension—eliminating gouging, hammering.

Estimated ultimate oil recovery is 63 million barrels

produce the wells at capacity. This procedure caused a rapid loss of reservoir energy and well productivity and by 1924 it became necessary to resort to well-head vacuum to sustain production. This vacuum averaged 24 to 25 inches of mercury by the end of 1926, and it has been maintained in this order to the present time.

Gas repressuring. In 1934 one of the operators instituted gas injection on one of its leases in an effort to check declining production of the lease, which at that time amounted to 420 barrels per day. By 1937 production from this lease had increased to 550 barrels per day under the stimulant of gas repressuring. Prompted by the benefits and promise of this initial gas injection operation, the operators inaugurated a general field-wide cooperative repressuring program in September 1937. At that time the field total production was 2,010 barrels per day and under the repressuring program increased to a peak of 2,680 barrels per day in August 1943.

The field repressuring program currently employs 24 input wells located throughout the field on irregular spacing. Approximately 1,450 Mcf of gas is injected daily at these wells, with individual well input pressures ranging from a vacuum to some 200 psig. Injected gas consists of residue gas from the field's gasoline plants and purchased outside gas. The field currently produces at an average rate of 1,500 barrels of oil per day from 233 wells, for an average of 6.4 barrels per well per day. Of this total field production, 500 barrels per day, or 33 percent is due to repressuring, based on extrapolation of the estimated unrepressured production decline trend. During the past seven years the field overall production decline has been at a rate of only 5 percent per year. During this period gas injection has remained relatively constant at 1,400 to 1,500 Mcf per day and gas production has been rather stable at some 1,900 Mcf per day. Because of the slightly declining oil rates during the time, the produced gas oil ratios have risen from 700 to near 1,200 cubic feet per barrel. Gas channelling has presented no serious problem although gas oil ratios are high in some of the upstructure areas of the field which have undergone advanced stages of depletion. Water production, which is of only minor proportions, is confined to the flank leases. Because water drive activity is nil, the water-oil contact has remained essentially unchanged at its original level of 1,115 feet subsea.

As of Jan. 1, 1958, accumulated oil production from the 1,300 productive acres was 52.5 million barrels, of which 6.3 million barrels or 12 percent is assignable to the field gas repressuring program. This total oil production gives a recovery of 40,300 barrels per acre to this time. It is estimated by extrapolation of the production decline curve that ultimate oil recovery will approximate 63 million barrels. This ultimate recovery will represent 61 percent of the original oil in place. Production statistics are plotted in Figure 4.

The unusually high oil recoveries in North Homer, currently 51 percent and ultimately 61 percent of the oil in place, reflect the effectiveness of the operating practices in the field. Recognizing that the field owes its favorable status largely to the repres-

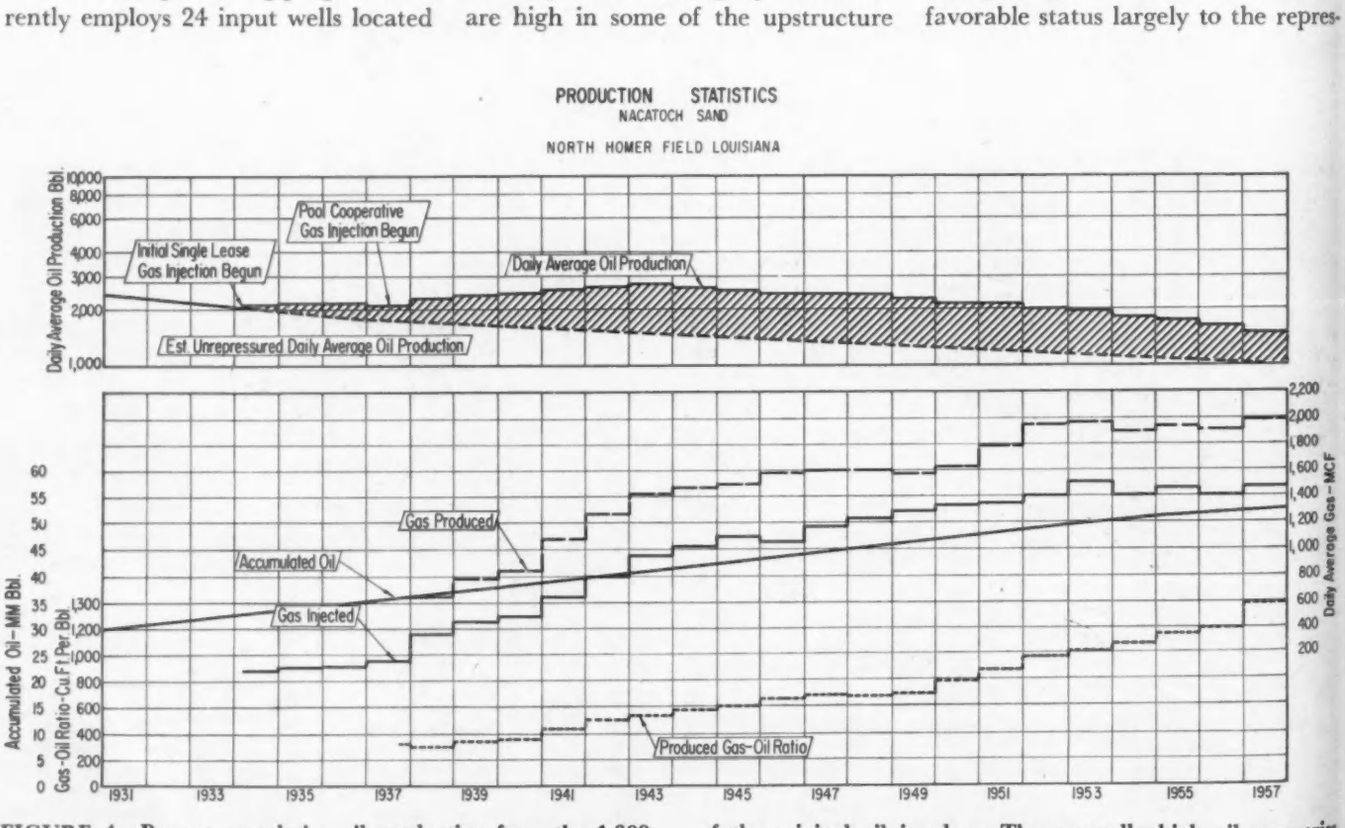


FIGURE 4—Present cumulative oil production from the 1,300 acres was 52.5 million barrels as of Jan. 1, 1958. Estimated total oil recovery will approximate 63 million barrels, or 61 percent of the original oil in place. The unusually high oil recoveries reflect the effectiveness of field operating practices. The favorable status of the field is largely due to the gas repressuring program.

CUSTOM BUILT ESPECIALLY
FOR DEEP, HARD-TO-PUMP WELLS

oilmaster

unit barrel pumps

In the age of the atom, marvels have become commonplace, but one of its marvels has made it possible to fabricate the uncommonly fine Oilmaster Unit Barrel. It has only been known in recent years that certain iron base alloys rich in nickel would undergo a structural change when subjected to extreme cold—a permanent change in the crystalline structure which improved the hardness and abrasion resistance of the alloy, but more important, caused the alloy to grow, and retain a permanent growth when it returned to atmospheric temperature.

This knowledge paved the way for the development of the Oilmaster Unit Barrel*, where a special analysis of centrifugally cast Ni-Hard is accurately machined into sections which are expanded into a precision honed alloy steel jacket and transformed into an integral unit by application of refrigerant at temperatures of more than 100° below zero.

But atom age or not, only the oil well can tell the difference—and the oil well has shown the Oilmaster Unit Barrel to be beyond question the finest pump barrel that has been produced. Call your OILMASTER representative and ask about equipping all of your deep, hard-to-pump wells with Unit Barrel Pumps.

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Export: The National Supply Co., Export Division,
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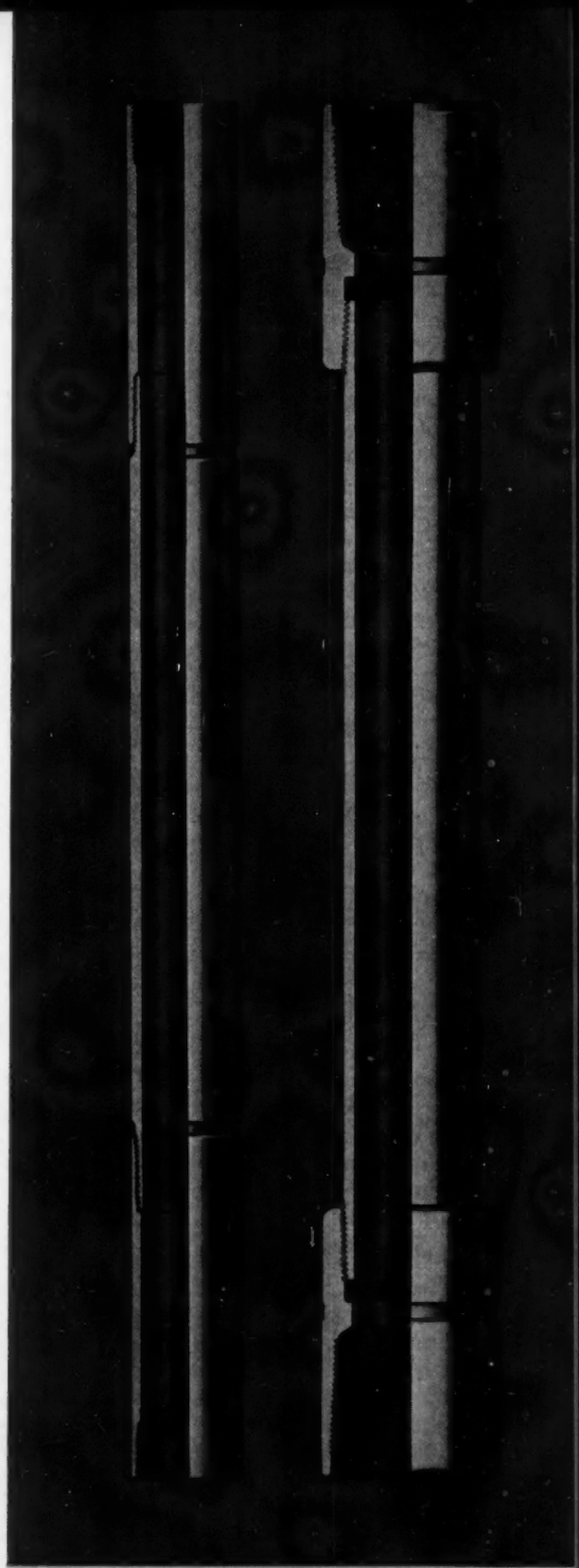
*U.S. Patent No. 2,647,847



A premium barrel of special construction designed for insert or tubing type pumps.

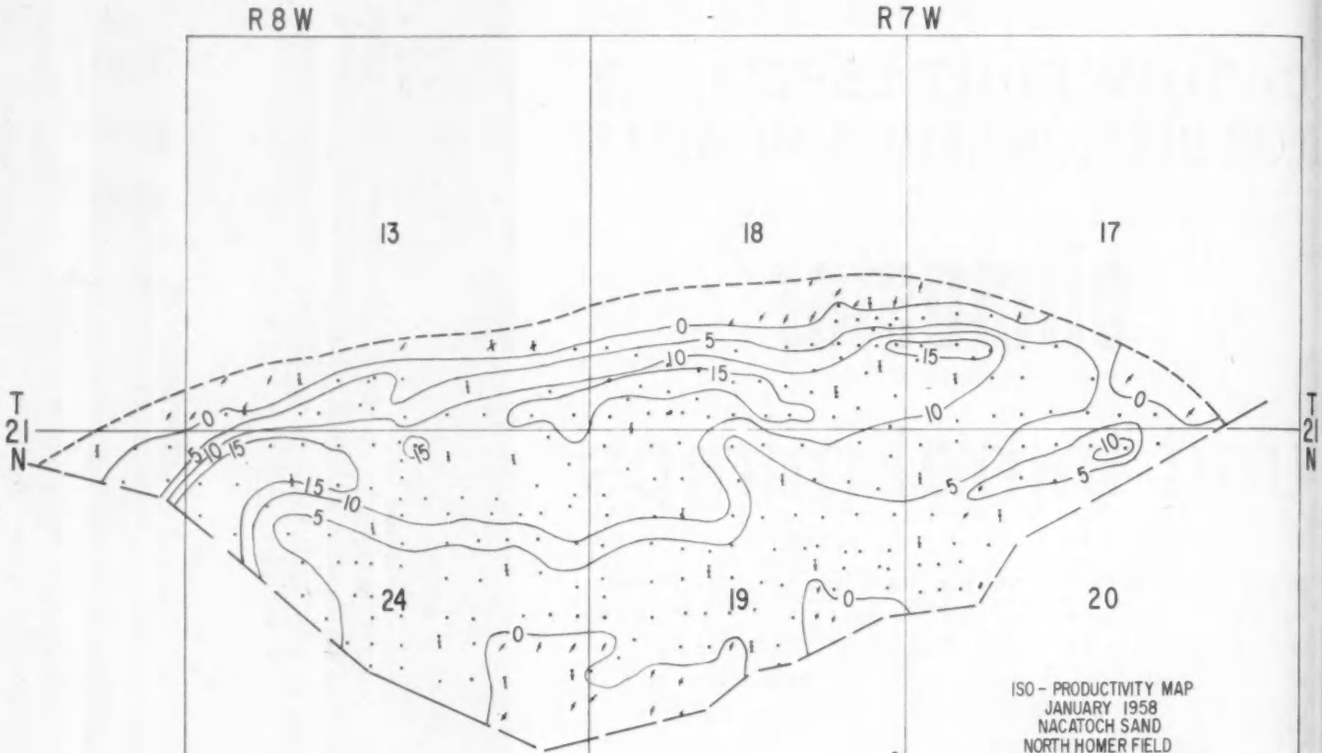


FIGURE 5—This iso-productivity map of the North Homer field illustrates benefits provided by gravity drainage to down-structure areas.

suring program, the operators are continually striving to effect improvements in the program. Steps taken to this end include concentration of injection in specific areas where response is greatest and adjustments in input rates on an individual well's basis in order to locate and make best use of the more efficient input wells. Such steps insure highest gas sweep efficiencies and maximum return on expenditures for injected gas.

Effects of gravity drainage. The comparatively step dip of the structure, 500 feet per mile, has caused gravity drainage to exert an influence on productivity. The effects of gravity drainage are clearly evident by the fact that the higher production wells are located in structurally low areas of the field. Figure 5, an iso-productivity map, illustrates the benefits of gravity drainage to the down-structure areas. Well productivity varies from less than one barrel per day in the structurally highest wells to over 15 barrels per day at some of the downdip wells. —**The End**

About the Author

Paul R. Waddle, a member of the consulting firm, Brookings, Moffatt & Waddle, Shreveport, received his B.S. degree in petroleum engineering from the University of Oklahoma in 1943. He worked for The Carter Oil Company from 1945 to 1957 in Kansas, Oklahoma, Arkansas, Louisiana, Mississippi and Alabama, attaining the position of division reservoir engineer in the Southern division at Shreveport. Waddle received special reservoir training at Carter's Research Laboratory and assisted in teaching reservoir engineering at the special reservoir engineering schools conducted annually by the Research and Production departments of Carter in Tulsa. He resigned from Carter in 1957 to enter the engineering consulting practice and recently became associated with his present concern.

ERRATUM—The legend on this illustration, which appeared on Page 124 of the June issue of WORLD OIL, was reversed. The corrected illustration is herewith presented.

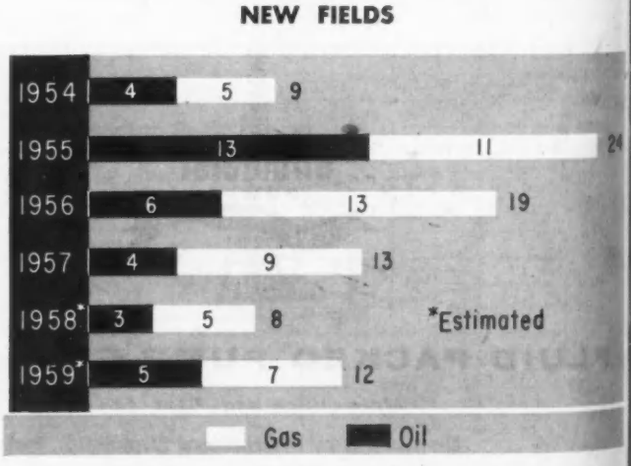


FIGURE 3—Wildcat drilling has had phenomenal success along the Louisiana coast. A 33 percent success ratio, compared to a national average of 11 percent, has been established.

Optimum water-flood development

Continued from Page 116

2. Project life is primarily dependent on the capacity and number of injectors for a given project with sufficient producer capacity.
3. Development cost is mainly a function of well density and operating cost of project life for any given project. Development and operating costs are inverse functions as spacing is changed.
4. Basic development controls limit the number of feasible project development plans.
5. Optimum development can be determined by detailed economic analysis of all feasible programs.

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[7] Kenneth G. Miller, *Oil & Gas Federal Income Taxation*, Commerce Clearing House, Inc., 1957.

About the Author

Bert Murphy is a Texas registered professional engineer with a B.S. degree in petroleum engineering from Stanford University. He has done graduate work in reservoir engineering and evaluation at the University of Southern California. In 1948 and 1949 he worked with Continental Oil Company and in 1950 joined Signal Oil & Gas Company where he advanced to project engineer and supervisor of a West Texas flood project. In 1954 he was engaged as chief engineer by F. Kirk Johnson and was made assistant manager of their water-flood division just prior to the incorporation of the firm which became Ambassador Oil Corp.

In April of 1957 he resigned from Ambassador Oil Corporation together with Curtis McBroom, former Ambassador vice president and manager of the water-flood division. Together they formed Water-Flood Associates, Incorporated, a consulting and operating company. Murphy is vice president of engineering and operations for this concern.

Fresh Water Fracturing

Continued from Page 120

tion increases were studied to determine why the response was unsatisfactory. Emulsions did not occur in any of these although silicate swelling or formation swelling of bentonitic materials caused two of the failures. However, both of these wells showed only slight decreases in production. Two of the failures can be credited to failures in application. Five were dry holes and were plugged and abandoned. In these five cases, treatments were performed only as a last resort and because the use of water made an inexpensive treatment possible. Water zones were opened in four of the failures; in the other nine cases it was impossible to determine what caused the lack of response. All nine of these wells were among the group that did not change in production.

A review of the over-all picture of the first 100 treatments revealed that the average production per well before fracturing was 4.98 bopd and 3.08 bwpd. The production after treatment averaged 32.32 bopd and 47.15 bwpd. Thirty days after treatment, the average production per well was 27.95 bopd and 23.04 bwpd.

Table 4 summarizes the first 100 fresh water fracturing treatments in the Permian Basin by formation. It can be seen that the percentage of successful treatments is high in those formations containing appreciable amounts of salt in the crude oil, formation water or formation rock.

Case Histories. A new completion in the Dunes pool, Grayburg formation, was fractured with 24,192 gallons of fresh water and 10,000 pounds of sand. According to the prediction chart, this well was given a good or excellent chance for successful stimulation. The salt content of the crude was high, but the brine's salt content was low. A core was not available to determine the salt content of the rock. Tests for emulsions and silicate swelling were favorable. Before the treatment, the well had only a show of oil and gas. On the seventh day following treatment, the well made 103 barrels of oil and 4 barrels of water. Thirty days later the well was making 118 bopd and no water. The total amount of water recovered from this well was 19,500 gallons, of which the average salt content was 7.9 percent. This represented the removal of 13,650 pounds of salt from the formation. Offset wells in the same vicinity, normally treated with 20,000 gallons of lease oil and 10,000 pounds of sand, do not respond as favorably as this well did.

A treatment was performed on an old producer in the Vaughn pool, completed in 1946 in the San Andres formation. The treatment used 20,454 gallons of water and 10,000 pounds of sand. This field produces crude and brine with high salt content, although the amount of brine produced is small. The salt content of the rock was not known. It was expected, however, that a fresh water fracturing treatment would help this well because salt deposits from produced fluids were undoubtedly present. Production before the treatment was 6 bopd and no water. Ten days after treatment, production was 86 bopd and 10 bwpd. After 30 days, oil production was up to 100 bpd and water production was down to 5 bpd. After 60 days, no water was being produced and oil production was 132 bpd. Only 5500 gallons of the 20,454 gallons of injected water were recovered. The brine content of the returned water was 4.6 percent, representing a removal of only 1926 pounds of salt. Previous fracturing treatments in this area using oil-base fluids had not been very successful, largely because of the low bottom hole temperature and low productivity of the wells. Upon completion the wells had responded to acid treatments.

A fresh water fracturing treatment using 28,000 gallons of water and 20,000 pounds of sand was given a well in the Shafter Lake pool, Yates formation. This well, completed in 1952, is in an area where the salt content of the crude is high. Salt content of the rock is now known to be about 29 pounds per cubic foot, indicating that this formation would probably benefit much more from fresh water than oil treatments. This well did not produce any oil or water before treatment. Seven days after treatment, it was producing 92 bopd and 6 bwpd. After 30 days, it produced 91 bopd and 5 bwpd. At the end of 90 days, production was 48 bopd and no water. The total water recovered was 18,000 gallons, with a brine content of 23 percent. This represented the removal of 40,140 pounds of salt from the formation.

ACKNOWLEDGMENT

Presented at the Permian Basin Oil Recovery Conference, Midland, Texas, April 18-19, 1957. Sponsored by Permian Basin Section, AIME and Texas Petroleum Research Committee.

For Your PRODUCTION File

Part 1 of a new series on reservoir engineering

Saturation pressure —a reservoir evaluation tool

Saturation pressure can be an invaluable aid in planning drilling programs for newly-discovered oil reservoirs.

By Frank W. Cole
Assistant Professor Petroleum Engineering
School of Petroleum Engineering
University of Oklahoma, Norman, Okla.

THE TERM saturation pressure is familiar to all petroleum engineers. Briefly stated, saturation pressure is defined as the highest pressure at which a bubble of gas will be evolved from solution from the oil as the pressure is decreased. If analysis of a subsurface sample shows that the saturation pressure is substantially equal to original reservoir pressure, it can be presumed that the reservoir has a gas cap. Conversely, if the saturation pressure of the subsurface sample is well below the original pressure of the reservoir, it can be assumed that the reservoir does not contain a gas cap.

In addition to its more common uses, proper interpretation of saturation pressure obtained by analysis of a subsurface reservoir fluid sample from a new reservoir can aid the engineer who is planning additional development wells for this new reservoir. For example, if a subsurface sample analysis from the first well drilled showed the saturation pressure to be 1,000 psi less than reservoir pressure, it can be reasonably assumed that the reservoir does not contain a gas cap. This would probably hold true for any reservoir, although there are some factors which could modify this concept for steeply-dipping reservoirs. An upstructure well, therefore, could be drilled without too much risk of it being drilled into a gas cap of the oil reservoir, since the evidence points to the complete lack of a gas cap.

According to Henry's Law, as pressure increases the solubility of gas in oil also will increase. If an oil reservoir has an associated gas cap, it can be assumed that the oil is saturated with gas. The passage of geologic time normally will have been sufficient to insure the attainment of equilibrium conditions between the gas and oil. At a point several hundred feet below the gas-oil contact of a steeply-dipping reservoir, saturation pressure would be considerably higher than the saturation pressure of the oil at the gas-oil contact, but the oil would still be saturated, i.e. gas would be evolved from solution when the pressure was lowered.

If the saturation pressure of a subsurface sample were approximately equal to the reservoir pressure a gas cap would be indicated. It would be impossible, however, based on saturation pressure alone, to determine whether the sample had been obtained either close to, or far away from, the gas cap. In any event, considerable caution would be in order before drilling an upstructure well.

The preceding discussion assumed that a subsurface reservoir fluid sample has been taken which is representative of the reservoir fluid. On a new reservoir, a simple method of ascertaining whether the reservoir sample actually is representative of the reservoir fluid, is to compare the original gas in solution determined from the reservoir fluid sample with the actual produced gas-oil ratio. These two gas-oil ratios should be equal until reservoir pressure drops below saturation pressure. At that time gas will be liberated from solution from the oil remaining in the reservoir. Thereafter, a comparison of produced gas-oil ratios with gas solubility data from a subsurface sample analysis becomes more difficult.

TO BE CONTINUED

Numerous companies are active in Libya

Oil is being sought vigorously in Libya, northern Africa.

Nearly 20 U. S. companies are operating in Libya or hold concessions there, along with the French Compagnie Francaise des Petroles, the British-Dutch Royal Dutch-Shell Group, and Britain's D'Arcy Exploration Company (British Petroleum Company subsidiary).

There are now eight drilling rigs in Libya, located throughout the country. At work in Libya are 17 seismograph crews, 21 gravity meter crews, 26 surface parties, 8 topographical crews and 19 mine clearance teams that stay busy combing the area for dangerous remnants of the last war.

All counted, there are about 500 Americans in Libya engaged in oil operations. One company alone (Oasis Oil Company) has 42 Americans employed in its operations.

The search for oil in Libya has been stimulated by the French discoveries of several major fields in the Sahara desert in adjacent Algeria and by a recent oil discovery in the southwest of Libya itself.

The only productive well in Libya began yielding oil in late 1957. It was drilled by Esso Standard (Libya) Inc., a subsidiary of Standard Oil Company (New Jersey). The discovery well, Haghe 2, was located in the Fezzan, southwestern Libya, 75 miles southeast of the Edjele field of Algeria. The well was considered capable of yielding 250 barrels per day of 45 gravity oil from Ordovician sand at 2,100-2,140 feet.

The same company (Esso Standard) in late May was making slow and costly progress in drilling its wildcat at el Jahama in the Syrtic desert. A week's drilling in a particularly tough layer of rock resulted in deepening the hole only 52 feet. The depth was 9,999 feet at the beginning of the week and 10,051 feet at the end. And nothing but hard work was in sight.

At the same time Mobil Oil Company of Canada (Socony-Mobil Oil Company, Inc.) was drilling at 6,106 feet at Hofra in the Syrtica.

Oasis Oil Company of Libya is prepared to go as deep as 15,000 feet in its wildcat, Bahi 1, 75 miles south of the Gulf of Sirte, on concession No. 32 in Libya.

International Drilling Company, N. V., is contractor for the well. Heavy duty rotary and drill pipe are being used.

The wildcat will test a long north-south trending anticline, mapped by Oasis Oil geologists. A seismograph survey confirmed the surface work.

Oasis Oil Company of Libya is a wholly-owned subsidiary of the Ohio Oil Company. Oasis is the operating company for Libyan concessions totaling nearly 62 million acres. Ohio Oil, Continental Oil Company and Amerada Petroleum Corporation hold undivided one third interests in the concessions.

Bahi 1 is the first well to be drilled on the group's concessions. It had drilled below 2,500 feet by the middle of April.

Another significant wildcat is being drilled in Libya. It is the first Libyan deep test of D'Arcy Exploration Company (Africa) Limited. That company is one of the prospecting subsidiaries of the British Petroleum Company Limited.

D'Arcy's wildcat, known as Castel Benito No. 1, is located about 30 miles south of Tripoli. This first test well is being drilled following several years of survey work in Libya by British Petroleum Company. The company has concessions in all three provinces of Libya—Tripolitania, Cyrenaica and the Fezzan.

The 62 million acres held by Continental, Ohio, and Amerada represent the most extensive concessions of any group in Libya. The second largest holdings are the 24,519,000 acres held jointly by The Texas Company and Standard Oil Company of California. Esso Standard (Libya) Inc. ranks third with 24,463,000 acres under concession.

Other American companies holding concessions in Libya include the following: Drilling and Exploration Company, Inc., W. R. Grace & Company, Gulf Oil Corporation, Hunt International Petroleum Company, the Libyan American Oil Company (Texas Gulf Producing Company), Pan American International (Standard Oil Company of Indiana), Santa Fe Drilling Company and Southern California Petroleum Corporation.

Though King Idris of Libya is pro-Western, as is his government, still oil men there are plagued by rules and regulations which make their jobs difficult. There have been instances of supplies being held up in unnecessary delays in ports, as well as other inconveniences. Also, there has been noted an alarming increase in the amount of Communist propaganda, which is going on uncurbed.

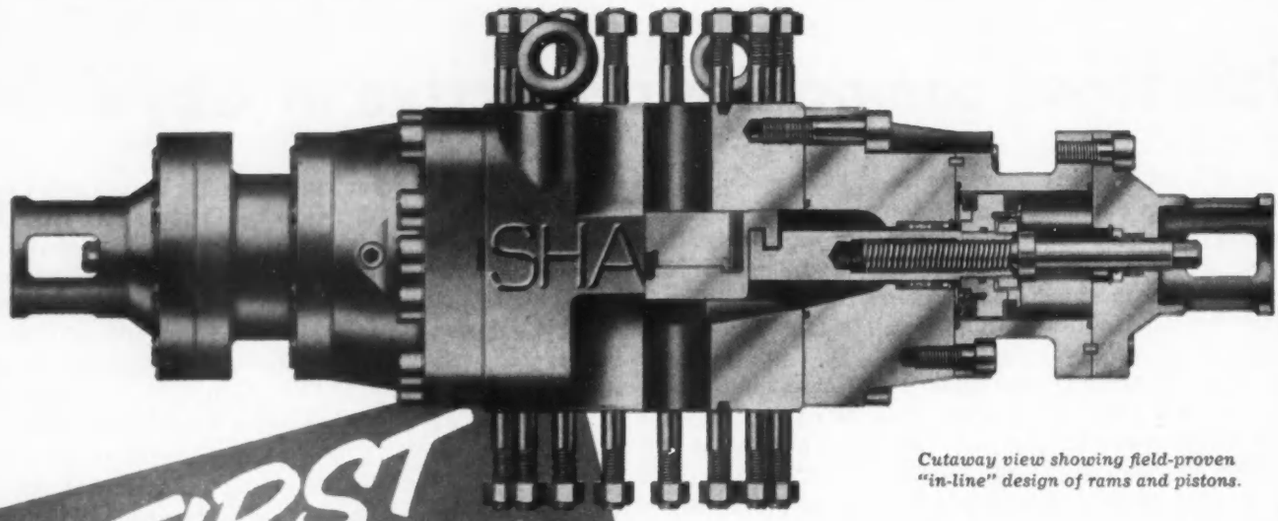
Americans in Libya are hopeful that an oil pipe line will be built from the southwest of Libya and from the highly productive Edjele field in Algeria across the desert to Tripoli on the Mediterranean. From Esso Standard's discovery well it is over 350 miles north to the Mediterranean coast.

However, large oil reserves, probably at least 200 million barrels, would have to be proved up to make field development and construction of a pipe line outlet profitable, at least within the next few years.

The Bechtel Corporation is reported to have signed a contract with the French oil operators in the Sahara to build a 16-inch pipe line, costing $90 million, to Tripoli. But the start of construction hinges on securing the permission of the Libyan government and on raising funds for the job. The Libyans are reluctant to do business with the French while their neighbors, the Algerians, are fighting to gain their freedom.

Less than three years after passage of the Libyan oil law of 1955, the petroleum industry is already by far the largest and most active industry in the country.

Another big FIRST BY SHAFFER...



Cutaway view showing field-proven "in-line" design of rams and pistons.

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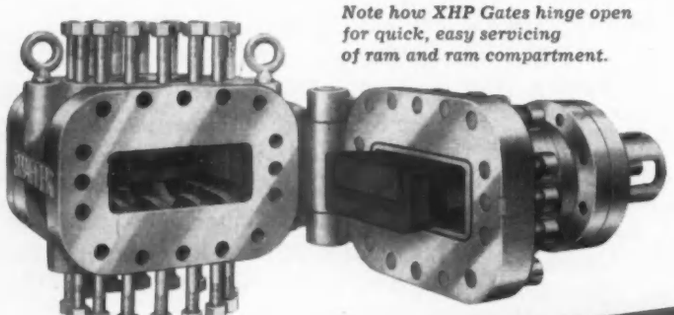
Not only is this XHP equipment in full production (not just in test and development stages) but many units are in actual field service in various high-pressure oilfields throughout the world!



Note how XHP Gates hinge open for quick, easy servicing of ram and ram compartment.

XHP HIGHLIGHTS

XHP equipment embodies no new, untried operating principles. Its basic design features are only those operating principles that have been field-proven over years of rugged oilfield service!

XHP equipment features the same "in-line" design of rams and hydraulic cylinders that has proven so efficient on other Shaffer Hydraulic Gates. Fewer parts, simpler maintenance, greater safety!

XHP equipment incorporates an advanced *hinged body* design that greatly simplifies changing the rams as well as servicing the ram compartment.

XHP equipment can be swung open without breaking fluid lines because the fluid pressure travels through passages machined directly into the hinge pins.

* **XHP** equipment is available in 7-1/16", 9" and 11" bore sizes and all sizes are inspected and individually tested. The 7-1/16" bore size is tested to 22,500 PSI for *working* pressures to 15,000 PSI. The 9" and 11" bore sizes are tested to 15,000 PSI for *working* pressures to 10,000 PSI. All sizes can be furnished either Studded Flange or Bolted Flange type.

There are many other important features built into Shaffer XHP Hydraulic Gates. See your nearest Shaffer representative for complete details—or write direct!

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Burning Well Signifies New Oil Area

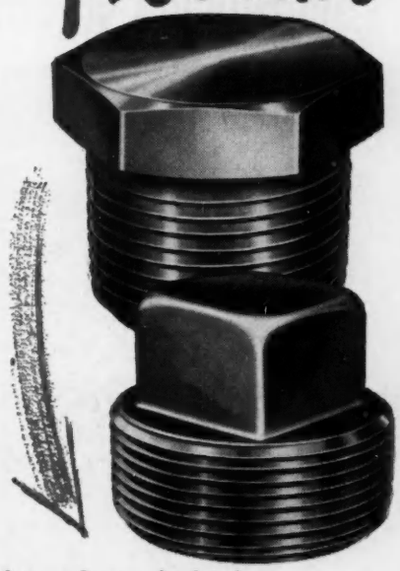
Southern Iran has gained a new producing area "the hard way." Iranian Oil Exploration and Producing Company's wildcat, Ahwaz 6, yielded a strong flow of sulfur-free gas, estimated at 100 million cubic feet daily, along with some condensate from 7,754 feet. The well then blew out and caught on fire. It appeared that after the original gas blowout in mid-April the fire was fed by gas and high pressure jets of crude oil from the casing and a lower pressure spray below the derrick floor level. Myron Kinley, Houston oil well fire fighter, was called on to extinguish the fire and cap the well. The wellhead was cleared and wreckage was removed. A 13⅜-inch casing flange appeared to be intact. A 6-inch water line was built from the well to the Karun River, 20 miles away. A relief well was being drilled toward the bottom of the burning well in May and early June, so as to pump in water and kill the oil and gas flow. The photograph herewith shows the burning well, Ahwaz 6, and equipment brought to the scene for capping the well. The picture was supplied to WORLD OIL by Iranian Oil Participants, Limited, London.

Brur Oil Field in Israel Looks Smaller Than Heletz

The new Brur oil field in Israel, located a few miles south of the Heletz field, probably will be smaller than Heletz. Sand development at Brur is erratic, and the pay is missing at the top of the structure, apparently. One geologist expects a five or six well field.

A deep test at Heletz reached about 10,000 feet, where drilling was suspended due to technical difficulties. A larger rig was being moved on location to drill deeper, perhaps to 14,000 feet.

plugs for Pressure



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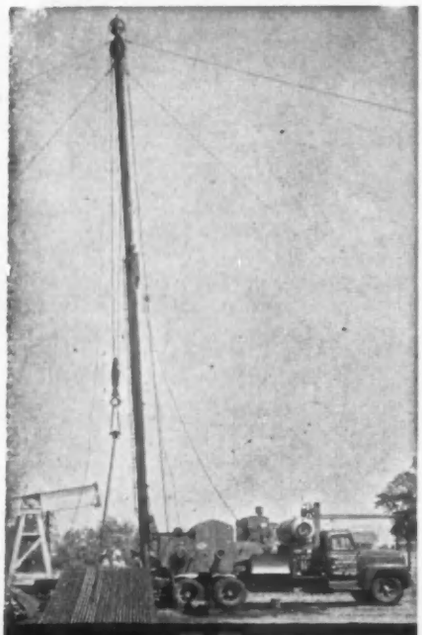

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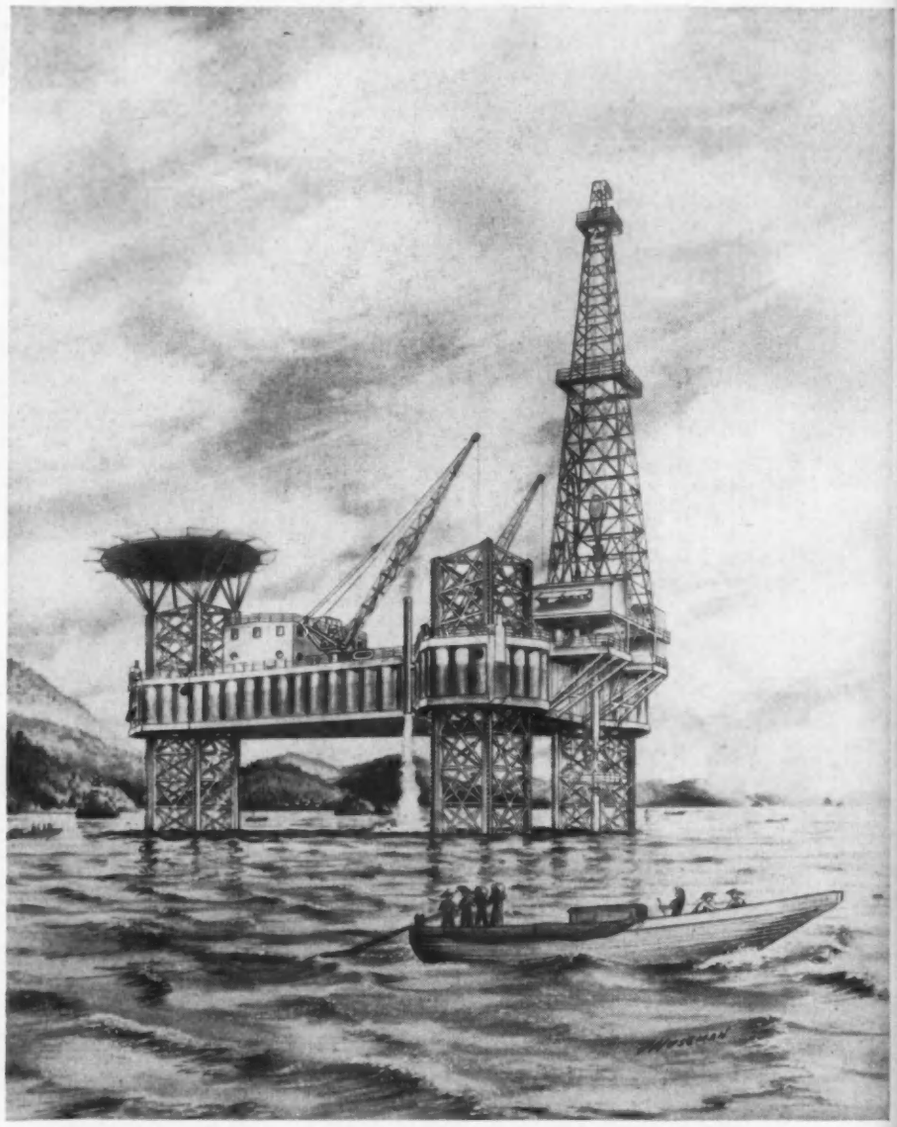


An offshore drilling platform will be built by Japanese interests and operated in the Sea of Japan. Hull and legwork of the 4,000-ton platform will be built by a Japanese ship yard. Technical guidance and some component parts will be supplied by a U. S. firm.

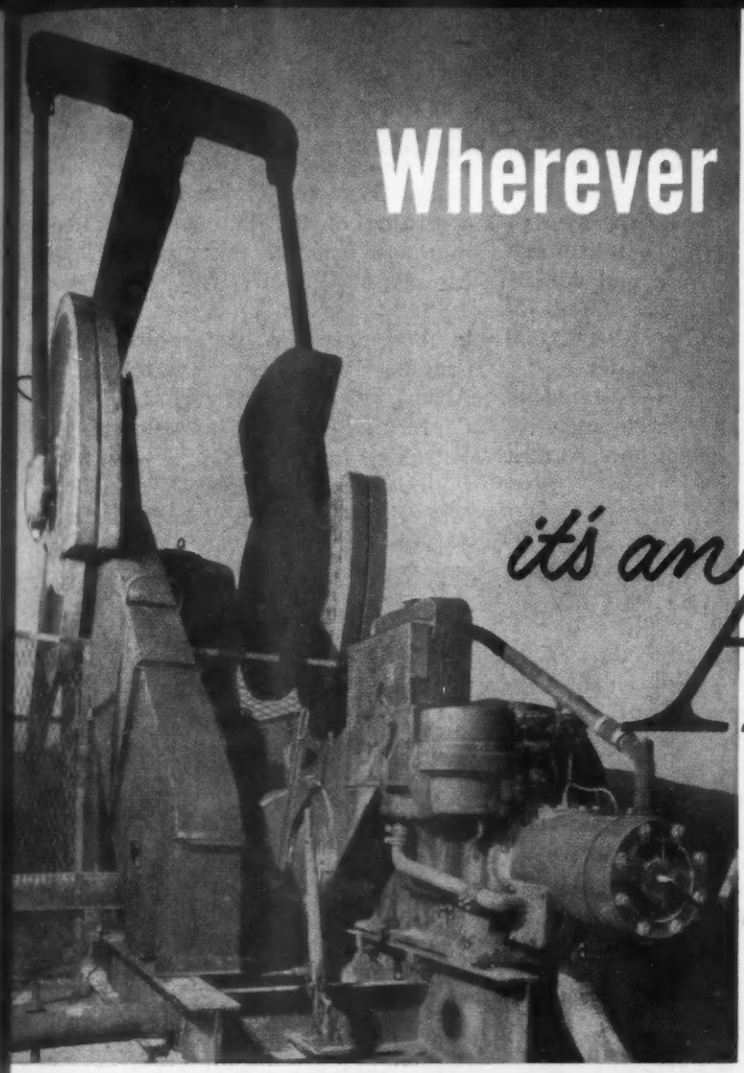
Japanese Push Plans for Offshore Oil Exploration

Japan's first offshore oil drilling platform will be built in Japan and put into operation there within the coming year. It will be owned and operated by Japan Petroleum Exploration Company, Ltd., of Tokyo ("Japex"). In construction of the platform, technical guidance and some of the more complicated component parts will be supplied by a U. S. Company. The hull and legwork of the 4,000 ton platform will be built by a Nipponese shipyard at Akita, under guidance of the U. S. company's engineers.

The Japanese government owns 56.5 percent interest in the "Japex" company. Principal non-governmental stockholders reportedly are 14 prominent oil refiners, including Teikoku Oil Company, Ltd., Idamitsu Kosan Company, Ltd., Koa Oil Company, Ltd., and others. It is believed that the first well will be drilled in the Sea of Japan, about one mile off the northwest coast of the main Nipponese island. Water there varies from 45 to 105 feet, and the ocean floor reportedly consists of rock and silt.

Mobile Drilling Platform In Use Off Saudi Arabia

Arabian American Oil Company's first mobile drilling platform was scheduled to arrive in Ras Tanura, Saudi Arabia recently after a 10,000-mile voyage from Vicksburg, Miss., where it was built. The triangular,



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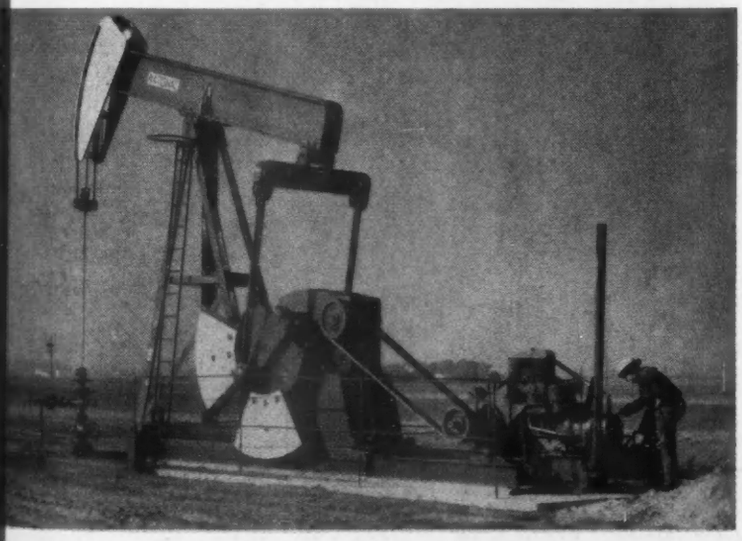

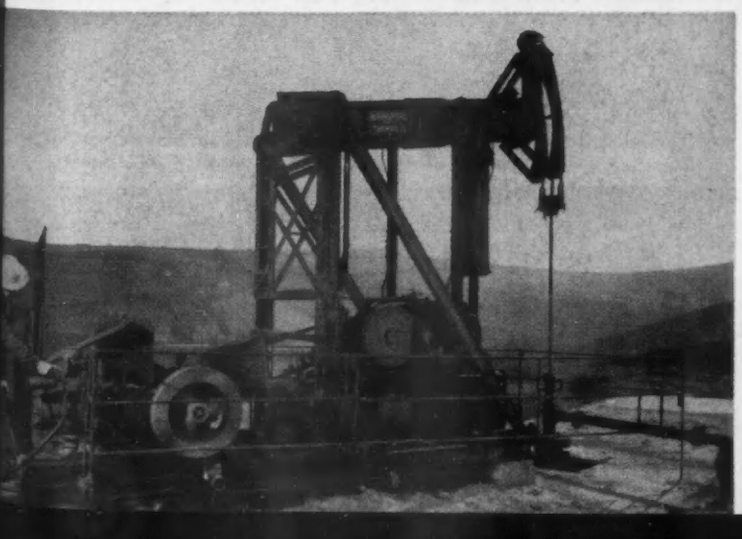

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three-legged platform weighs 800 tons without drilling equipment, is 93 feet long and 104 feet wide. Legs are 108 feet high.

When on location in the Persian Gulf, the platform will be 10 feet above the water surface and will be capable of drilling with a 136-by-30-foot standard derrick to about 13,000 feet in up to 65 feet of water.

The new platform is expected to be employed in the development of the newly-discovered offshore field at Manifa.

Good Fields Being Proved Up in Two Algerian Areas

The major Hassi-Messaoud oil field has been proved 12 miles long and 11 miles wide. Long stepouts continue to be drilled. Since the discovery in 1956, no dry holes have been drilled to limit the immediate field area.

Zarzaitine oil field, located near Edjele in far eastern Algeria, is expected to prove more profitable than Edjele. Zarzaitine structure probably covers a smaller area. But the oil pay is much thicker and has better reservoir characteristics than the thinner sands thus far proved at Edjele. Well Zr 2 penetrated 164 feet of oil-saturated lower Devonian sand from 4,360-4,524 feet, and flowed 3,200 barrels of 43 gravity oil daily from this pay, which is apparently not present at Edjele.

Geophysical exploration work is being conducted in the Sahara Desert of Algeria jointly by Phillips Petroleum Company and two French companies. The group holds a concession consisting of 815,430 acres, located in the vicinity of the prolific Hassi Messaoud oil field.

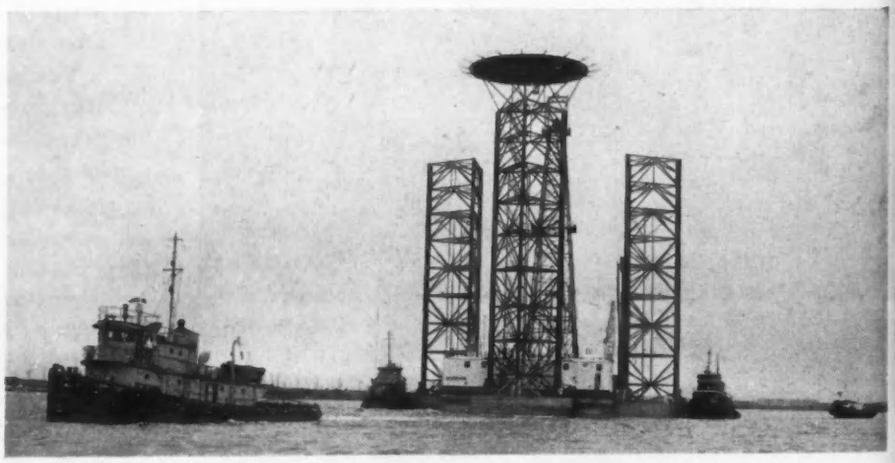
Phillips has a 25 percent interest in the venture, which represents the company's first entry into North Africa. The other companies are COPEFA (Compagnie Francaise des Petroles France-Afrique), which is the operator, and OMNIREX (Omnium des Recherches et Exploitations Petrolieres).

Oil Discovered in Gulf Of Paria by Five Firms

Oil has been discovered in the Gulf of Paria on the Venezuelan side. It was found by a group of five companies led by The Texas Company and also including Continental Oil Company, Ohio Oil, Cities Service and Richfield.

They discovered what appears to be a moderate-size field in their first test on a 152,000-acre block. Two rigs were to be operating on the block by the middle of 1958.

Any production found was expected to be comparable to the less prolific Trinidad fields to the east, as contrasted to richer fields in eastern Venezuela to the west.



Offshore Platform Travels to Bahamas

"The Scorpion," one of Zapata Off-Shore Company's self-elevating platforms, is here being towed from the port of Galveston, Texas, by a towing company tug, "The Grampus," toward a new marine location in the Bahamas, between Cuba and Florida. The location is on the Cay Sal Bank, 40 miles northeast of Cardenas, Cuba, 83 miles south of the Florida coast, and 187 miles southwest of Nassau, the Bahamas. Zapata is to drill a projected maximum 15,000 foot test in 30 feet of water for the Bahama California Oil Company, a subsidiary of Standard Oil Company of California, and Bahamas Gulf Oil Company, a subsidiary of Gulf Oil Corporation.

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Light, safe, and easy to handle Type "C" Drill Collar Slips have long, narrow, multiple segments individually hinged to freely conform to the drill collar and bushing surface. Drill Collar slips are made for all sizes of drill collars—from 3" diameter, to and including 10" diameter, in 5 basic body sizes. Body extensions provide a Safety Clamp seat and the carefully heat-treated alloy steel liners are easily replaceable.

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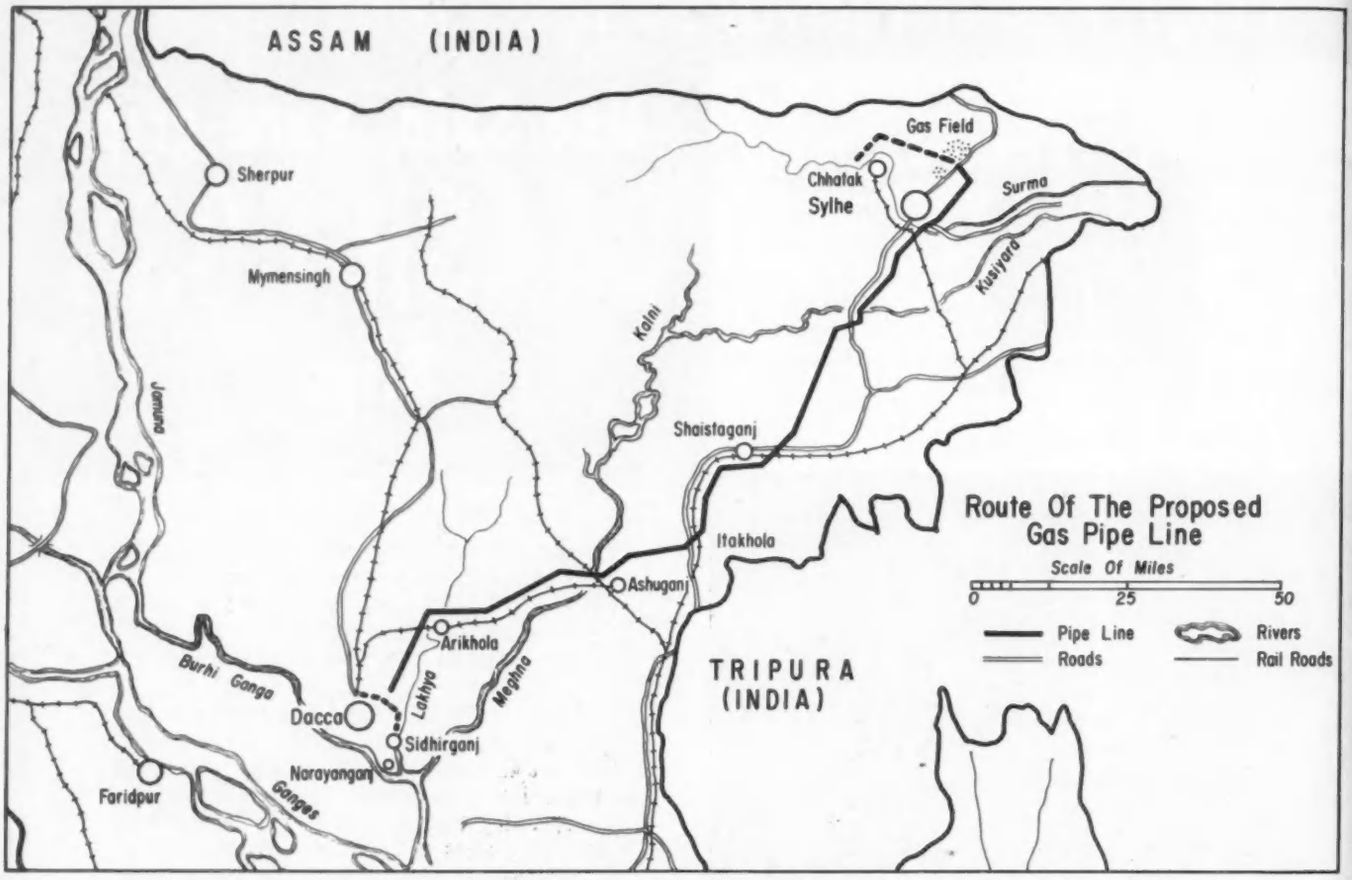


Gas field at Sylhet (upper, right) will feed gas through 8-inch pipe line to Dacca, 145 miles to the southwest.

Outlook good for East Pakistan gas field

East Pakistan's first gas field will have pipe line outlet. Plans call for 8-inch line to carry gas 145 miles southwest to industrial markets at Dacca. First well in area cratered and caught fire, second also hit gas, and third is now productive.

By Walter Sekules, London

THE FIRST commercial gas well in East Pakistan was brought in as a producer during the summer of 1957. Known as Sylhet 3, it is capable of producing 15 million cubic feet per day. Estimated possible reserve of recoverable gas is approximately 200 billion cubic feet. Open flow potential is more than 100 million cubic feet per day. As of the end of 1957 the well was shut in, awaiting outlets. It is completed in a zone of gas at about 4000 feet. The pay group of sands is about 500 feet thick at the dome summit. Some of the thick sands have good porosity and permeability.

Before Sylhet 3 was drilled a seismographic survey had to be undertaken in December 1956 and January 1957 to evaluate the producing structure indicated by Sylhet 1 and 2. Presence of natural gas here was first discovered in May, 1955, when Pakistan Petroleum Limited had its rig and equipment destroyed by a fire which broke out after Sylhet No. 1 well blew

out through a crater 200 yards from the well. It is believed the blow-out was triggered off by high pressure sands near the bottom of the well at 7800 feet. Drilling of Sylhet 2 started in May 1956 and by September it reached 9245 feet. It was closed in at this depth. A seismic survey was then undertaken before Sylhet 3 was drilled.

The Sylhet structure is a large exposed dome in Pliocene rocks. Down to 7500 feet rocks are Pliocene and Miocene sands with some shale intercalations, providing hard drilling below 4000 feet. Below 7500 feet the formation has been hard shale with thin sand bands which contain small quantities of gas with water at pressures above hydrostatic. At 9200 feet pressures of 9200 pounds per square inch were met before the well got into difficulties. Variations in pressure gradients and hard rock formations together with caving shale make deep drilling difficult because of the number of protective casing strings needed to consolidate progress. The casing program originally set up for Well 2 was as follows:

Surface Conductor	Depth	Hole Size
24½-inch	40 feet	20 -inch
16 -inch	300 feet	14¾-inch
11¾-inch	4,400 feet	10½-inch
8⅝-inch	8,500 feet	10½-inch
5½-inch	13,000 feet	7⅞-inch

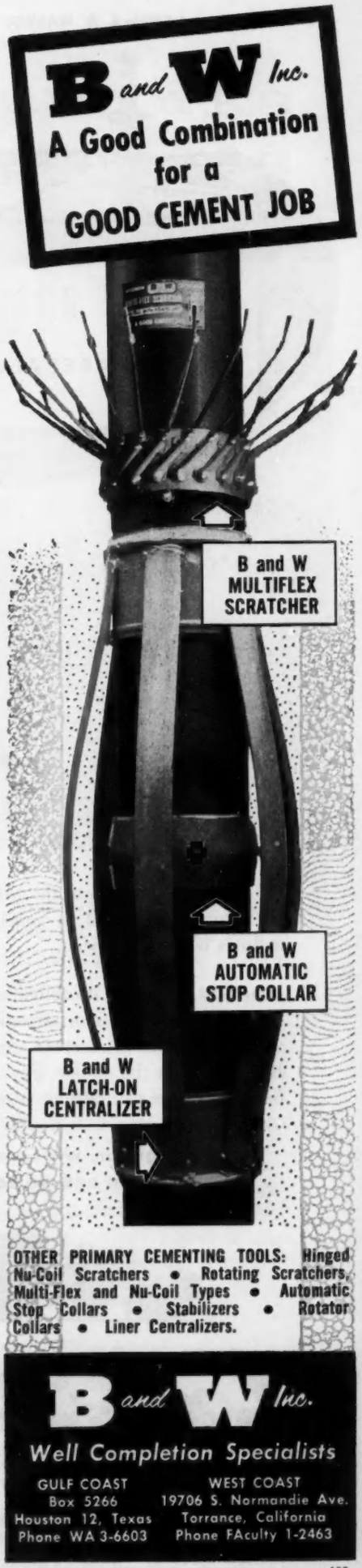
Another program is now being devised, however. Very deep drilling down to 13,000 feet or more may be needed in the search for permeable formations below the shale group—likely to present considerable drilling difficulties. Well 2 is shut in at 9245 feet with a high pressure water sand exposed and with 3500 psi on the blowout preventers. Well 3 has been completed as a producer from the 4000 feet gas sand.

Located near Haripur village in Pakistan Petroleum's 57 square mile licensing area, Sylhet is flanked by deep jungle to the west and south, and overlooks green paddy fields to the north. A National 50 rig was used to drill the well. Gas is almost pure methane and therefore will not need the complicated purification system which had to be installed at Sui, Pakistan's other major gas field.

The Sylhet gas field opens up the first potential source of indigenous fuel in the eastern half of Pakistan. Uses of the gas are still under discussion. Pakistan Petroleum Limited conducted a preliminary survey for the transport of the gas from Sylhet to industrial plants in Dacca and en route. This report recommended construction of an 8-inch diameter high pressure pipe line over the 145-mile route. This would give maximum utilization capacity of 24 million cubic feet of gas per day without compressors. The suggested route runs parallel to the main highway running south-west from Sylhet to the Kusiyara River, continuing south to Shaistagunj, roughly parallel to the East Bengal railroad from Shaistagunj to Itakhola, then parallel to the railroad from Ashuganj to Arikhola and veering south to a point on the Demra highway about five miles east of Dacca. In February, 1957 a practical construction plan for this route was drawn up by two Burmah Oil Company experts from London. Pakistan Petroleum Limited is also studying the possibility of laying a small diameter pipe line to supply gas to the Chhatak cement plant about 25 miles north of the Sylhet field.

Industrial offtake is most likely to be in cement plants and in a fertilizer plant. The government has yet to decide whether thermal power stations in the Dacca area should operate on natural gas and whether they should be primary producers or merely act as standbys to the Karnaphuli Hydel hydroelectric plants. If gas is not required for the Dacca power plants, the pipe line from Sylhet to Dacca would hardly be an economic proposition, as demand for power would not be large enough. It is now reported that the Pakistan Industrial Development Corporation has signed an agreement with Kobe steel works, Japan, for building a fertilizer plant capable of producing 250,000 tons per year, due to go into production during 1961. However, detailed specifications of the plant and its location have not yet been decided.

It seems possible from surface indications that gas will be found in other parts of East Pakistan. The outlook for oil is less certain. According to present evidence a very thick succession of hard beds with high pressure will have to be penetrated before reaching rocks which have some prospect of oil accumulation. —**The End**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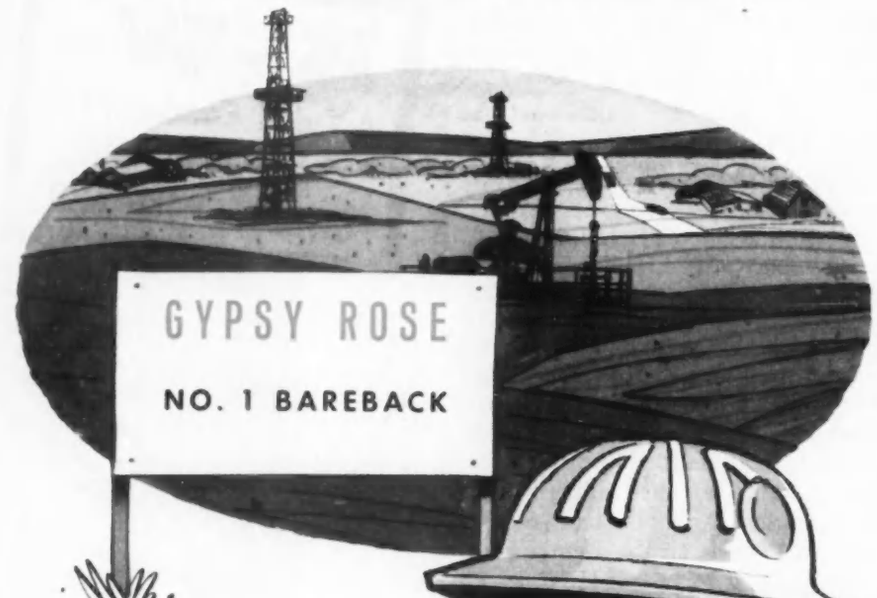

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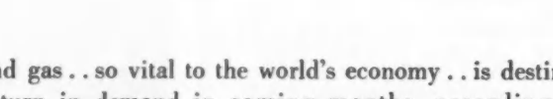

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Pan American and NIOC To Drill in Persian Gulf

The Iranian Parliament has ratified and the Shah has approved the recent agreement between Pan American Petroleum Corporation, a wholly-owned subsidiary of Standard Oil Company (Indiana), and National Iranian Oil Company. The agreement provides for development of a 16,000-square-kilometer offshore area (4 million acres) in the northern part of the Persian Gulf.

The concession is in accord with the new Iranian petroleum law passed in 1957, but each such contract must be ratified by the legislative body before it takes effect.

Under this agreement Pan American Petroleum Corporation and National Iranian Oil Company will form and jointly finance a non-profit joint stock company, to be known as IPAC (Iran Pan American Oil Company), which will act as agent of the joint venture in exploration, development and production of petroleum in the area of operations.

Pan American has agreed to spend $34 million on exploration operations in the first four years and an additional $6 million per year during the next eight years. Pan American may discontinue exploration without further obligation at the end of any year after the first four provided the obligation for exploration expenditures up to that time has been fulfilled. If a commercial discovery is made, Pan American may apply development expenditures against the total exploration obligation.

Exploration surveys will commence within six months, and drilling of at least one exploratory well will start within 18 months. Development and operational expenses will be shared equally by Pan American and NIOC.

The exploitation period is 25 years from the date of commercial production, with provision for three extensions of five years each.

Pan American agreed to pay to the Iranian government within 30 days a cash bonus of $25 million, about $6 per acre. In computing taxes due Iran, this bonus will be amortized over a 10-year period.

Both Pan American and NIOC will pay income taxes to the Iranian government equivalent to 50 percent of their net profits. There is a provision

for operating losses to be carried forward for 10 years.

No rentals will be paid during the first 12 years of the agreement. Thereafter rentals will be paid on a graduated scale, ranging from about $1.60 per acre in the 13th year up to about $2.50 per acre from the 24th year onward. Rentals are treated as a credit against Iranian income taxes.

Pure et al Find 600 Feet Of Pay in Maracaibo Well

The Centro Lago 4-X well in Lake Maracaibo, Venezuela, fourth well and best producer drilled by Pure Oil Company and three associates, has indicated that high rates of production can be expected from a second producing zone.

In a one-hour test of the Eocene C-6 sand, the well flowed at the rate of 3,800 barrels a day. The test was made through perforations between 12,284 and 12,353 feet. The flow was clean oil of 43.4 degrees gravity.

The same well previously was tested in the C-2 zone at 10,044 to 10,200 feet, and flowed 27.5 gravity oil at the rate of 5,136 barrels a day through a ¾-inch choke.

The well logged a total of approximately 600 feet of oil sand, which has been either tested or found productive in other wells in the area. Further testing of the well in the C-4 sand will be undertaken before the well is completed.

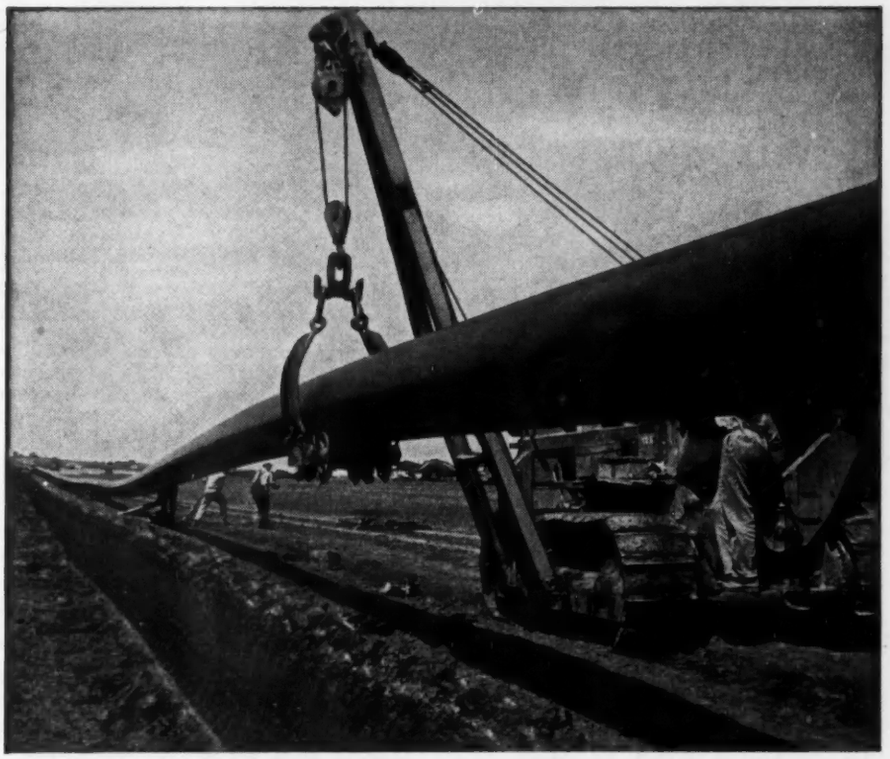
The associates, consisting of foreign subsidiaries of Pure Oil, Hancock Oil, Signal Oil and Gas and Standard Oil of Ohio now have two drilling rigs on their 28,000 acre Lake Maracaibo concession. Their fifth exploratory well, the Centro Lago 5-X, was spudded prior to May 1, when a second drilling barge was brought in to permit increased drilling activity.

The group's earlier 2-X and 3-X wells are large producers from the C-5 sand at about 12,000 feet. When they were drilled, the C-2 sand was encountered but not tested.

The group plans to deepen the 1-X well, on which drilling was suspended last summer at 9,470 feet.

Actual production from the concession is scheduled to begin late this summer, when terminaling facilities are completed at Punta Palmas, on the west shore of the lake.

Canada uncorks its gas resources



For Canada's vast, almost untouched supply of natural gas, outlets have already been planned to deliver over 10 trillion cubic feet to North American markets. Canadian gas reserves are expected by 1970 to approach 55 trillion cubic feet.

To bring this fuel to millions of future consumers, the great Trans-Canada gas line is designed to span the 2250 miles from Alberta to Ontario. Westcoast Transmission lines will carry British Columbian gas to the U. S. Pacific Northwest. A network of complementary lines will blanket Western Canada's fields. All this at a cost close to $600 millions by 1959.

The Canadian Bank of Commerce maintains a complete Petroleum and Natural Gas Department in Calgary, and more than 270 branches throughout Western Canada. For information on any aspect of the industry in Canada, write or telegraph to C. H. Munro, Manager, Petroleum and Natural Gas Department, 309 Eighth Avenue, West, Calgary, Alberta.

(*We regret that we cannot advise on the merits of oil or mining securities.*)

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The contract under which Conorado Petroleum Corporation was granted a permit to explore for oil in Tunisia is here signed. Signing, left to right, are W. F. Penniman, Conorado vice president; Hedi Nouira, Tunisian secretary of state for finance; and Azedine Abassi, Tunisian secretary of state for commerce and industry. Standing are Mr. Larram and Mr. Fourati, members of the Tunisian government staff.

Conorado Has Permit for Tunisian Oil Exploration

Conorado Petroleum Corporation became the first American oil company to initiate oil development in Tunisia since that North African country became independent last year. The only other oil company now active in the country is a joint French-Tunisian concern. Tunisia lies between Algeria on the west and Libya to the east and is southwest of Sicily and Italy.

Conorado obtained an oil exploration permit covering 11,000 square miles in the west central part of Tunisia. Conorado is owned by Continental Oil Company, The Ohio Oil Company, and Amerada Petroleum Corporation.

Conorado has agreed to spend $4 million in the next five years in search of oil in west central Tunisia. The concession territory is the historic area where the British, American and French armies met during World War II to start the final drive to push the German and Italian forces from Africa.

Gas Found at Fort Nelson In B. C., Western Canada

A major gas discovery has been made about 8 miles east of the town of Fort Nelson, British Columbia, western Canada.

Clarke Lake 1-A well of Gulf States Oil Company of Canada et al flowed gas in excess of 8 million cubic feet per day on drill stem tests from 82 feet of continuous dolomite porosity in the Slave Point section of the Middle Devonian formation. Drilling was discontinued, and the well was completed at 6,438 feet due to spring thaw of the Muskeg.

Gulf States, a wholly owned subsidiary of Western Natural Gas Company, jointly with El Paso Natural Gas Company earned a one-half interest from Imperial Oil Company Limited in the 252,672 acre Permit 195 by drilling this well.

The well is about 10 miles northeast of the Gulf States-El Paso, et al Prophet River 1 gas well at Milepost 290 on the Alaska Highway, completed last winter.

Clarke Lake 1, about 90 feet north of No. 1-A well, encountered Mississippian gas last January. It blew out of control at 1,867 feet, making 3 to 5 million cubic feet of gas per day. It was later plugged and abandoned because of mechanical difficulties. Clarke 1-A encountered gas in the same formation, but did not attempt to further test that zone because of limited time before the spring thaw.

Gulf States and El Paso own a substantial interest in an additional 500,000 acres located in the trend of production established by these wells.

New Drilling Records Are Set for Fields of India

Assam Oil Company drilling crews recently set three drilling records for India. At Nahorkatiya Well No. 33 they made a progress of 1,555 feet in one eight-hour shift. In the same well they drilled 3,110 feet in a 24-hour period. The well was spudded in on May 9 and reached a depth of 9,272 feet on May 28.

A third new record was that at Moran Well No. 9, drilling 3,320 feet while using only one bit. That well subsequently was drilling at 7,449 feet.

Well No. 992, the newest in Assam Oil Company's oil field in Digboi, is the deepest so far drilled in the area. It had reached 9,815 feet and was to be taken down to 10,000 feet. The previous record depth was that of 9,140 feet in Well No. 898.

Well No. 32 at Nahorkatiya was completed as a producer at 10,350 feet. It filled in between No. 1 and No. 2 wells. Out of 32 wells drilled so far at Nahorkatiya and Hugrijan, only five were complete failures.

Moran No. 8, completed in May at 11,695 feet, yielded encouraging results during a short production test. Out of eight wells in that area, only three were dry holes.

Japan's Oil Industry Is Active and Progressive

Formation fracturing is increasing in Japan. It is being used in many old oil wells and in new tests. Teikoku Oil Company's experimental insitu combustion project in Niitsu field is expected to prove successful. The first offshore test to be drilled off Akita in the Japan Sea by Japan Petroleum Exploration Company Ltd. was expected to spud in October, 1958. A total of 258 field wells and 78 wildcats were reported completed in Japan during 1957. Continuation of a booming oil industry there during 1958 was expected.

Russian Rigs Acquired For Drilling in India

Following seismic surveys, drilling is projected in India at Hoshiarpur in the Punjab, at Cambay in Bombay State, and at Sibsagar in Assam during midyear 1958. The Oil and Nat-

ural Gas Commission of the Indian government has acquired three Russian rigs to supplement the Rumanian rig drilling at Jawalamukhi in the Punjab.

During 1957 and 1958, the Commission was operating eight gravity parties, six seismic crews and 15 geological teams in Punjab, Cambay, Cutch, Rajasthan, Assam and other areas. Some core drilling is projected for these areas.

a WORLD of OIL

CUBA: Texaco Petroleum Company has commenced drilling in Las Villas Province on concessions covering 600,000 hectares, held with Cuban Gulf Oil Company.

EGYPT: Settlement of the Suez Canal dispute opens the possibility of a prompt settlement of the sequestration of Anglo-Egyptian Oilfields Limited. It is a Royal Dutch Shell group company. Its properties were taken over by the Egyptian government pending resolution of the Suez dispute with Great Britain.

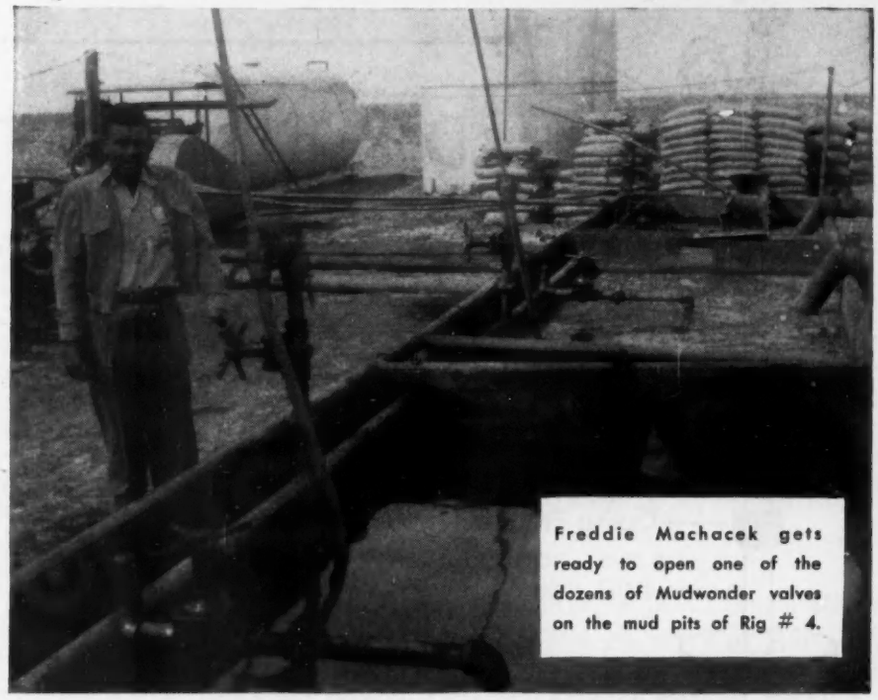
IRAN: Crude oil production in the Consortium area was 843,000 barrels per calendar day in April, 1958.

IRAQ: A deposit of extremely heavy, viscous crude has been found by Mosul Petroleum Company, 20 miles west of Fallujah. The company was expected to spud another wildcat on the Anah structure in Dulaim Liwa at midyear.

MALTA: British Petroleum Company interests were expected to reach agreement on new concessions with the Maltese and to drill a deep test on the Island.

VENEZUELA: The first shipment of LPG produced in Venezuela for export was loaded in May, 1958, at Creole Petroleum Corporation's La Salina dock number 3 aboard the M. S. Marian P. Billups. Bound for Caribbean markets, the LPG was produced at Creole's new Ule gas liquefying plant in Bolivar district.

Tips on Mud Valves for Toolpushers . .



Freddie Machacek gets ready to open one of the dozens of Mudwonder valves on the mud pits of Rig # 4.

MUDWONDER Ideal for Versatile Service

by Freddie Machacek, Toolpusher, Rig #4
B.B.M. Drilling Company, Midland, Texas

ABOUT two years ago I put a *Mudwonder* valve on our fill-up line just to see how it would make out. I soon found that *Mudwonder* worked fast and easily, without binding, even while bleeding off the line at 1600 lbs pressure. It did so well I tried more *Mudwonders* on the tough job of mud pit service—and they were so successful I've standardized on *Mudwonder* ever since!

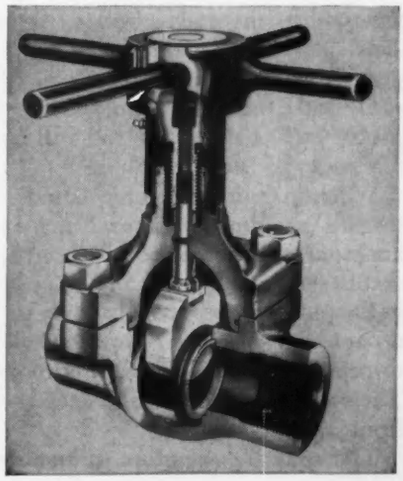
Valves on mud guns and jets take a terrific beating, but we've had very little trouble with *Mudwonders.* As a matter of fact, our first ones are still in service; we replaced the stem packing on one valve—that's all! Because replacement parts are so easy to identify, we never have any trouble getting the exact part we need. In fact, the valves are designed to use the same seat and gate for both pressure classes.

When we have to dress a *Mudwonder,* the job can be done without disturbing any connections. The valve is out of service only about 10 minutes, start to finish, regardless of size. Another thing—they never sand up. Bob Lawrence, Edward *Mudwonder* Representative, says this is because the design causes the mud to flush the bonnet automatically.

Mudwonder valves are available in 2", 3" and 4" sizes; with screwed or flanged ends; rated at 2000 psi WP (4000 psi test) and 3000 psi WP (6000 psi test). See your favorite oil field supply store for complete information, or write Edward Valves, Inc., East Chicago, Indiana, subsidiary of Rockwell Manufacturing Company.

(Adv.)

Mudwonder cut-away view shows the one-piece seat insert, with Buna-N molded integrally over steel wear rings; chromed gate with "T" slot connection; separated stainless stem and double thread construction.



For more data on advertised products, use Readers' Service Cards, last page.

DRILLING HINTS

These How-To-Do-It Ideas Can Save You Money

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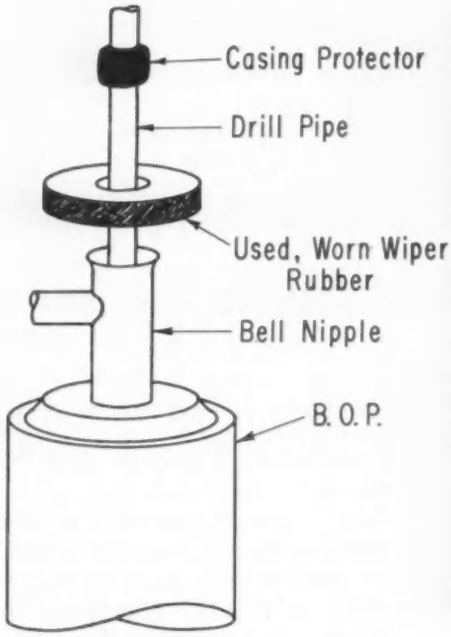
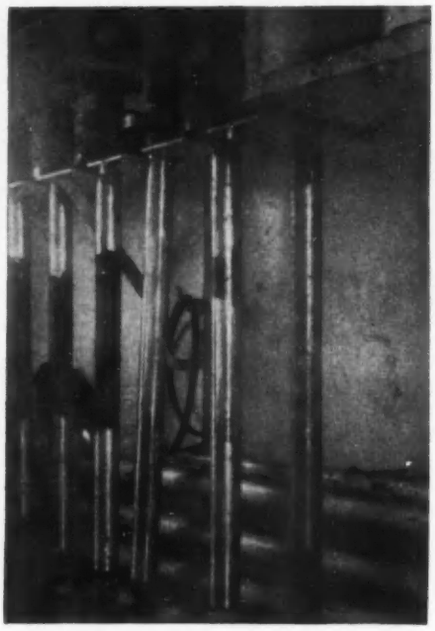


Provide Safeguard for Hole With Worn Pipe Wiper

Used pipe wiper rubbers can be used for protection while making a trip in the hole with bit or test tools.

The pipe wiper has come into widespread use the past few years as a means of cleaning pipe while pulling out of the hole. A number of old wipers can usually be found around any drilling rig.

A worn rubber with an oversized hole is installed around the drill pipe or tubing while running in the hole. The hole is enlarged enough so that casing protectors on the drill pipe can pass through with little or no drag. This prevents the protector from dragging the wiper down the hole. Installation of the wiper is an added safety measure against anything falling in the hole during the trip.

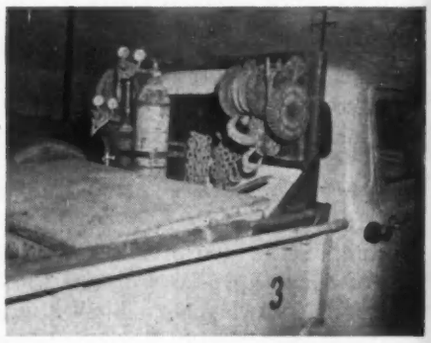


Construct Pump Rod Rack For the Parts House

The picture shows how one operator built racks to store different size pump rods and to protect the threads and polished surface of the rods. The rack is built of plate welded to the wall of the pump parts house high enough so the end of the rods, when hanging in the racks, will clear the floor. The lower part of the rack is slotted so the pump rods will slip easily into the slots. The packing or rubber end of the pump rod will hold the pump rods off the floor.

When hanging in this manner all threads are protected, and the rods are separated so their polished surfaces do not contact or touch any other part in the pump house. Rods in these racks do not have to be tied down or bolted to prevent their falling during moves. Their weight is sufficient to keep them from slipping.

The rods are therefore more accessible as replacement parts. The slots can be numbered so that any records being kept on the pump rods can be correlated easily.



Winch on Headache Rack Aids in Truck Loading

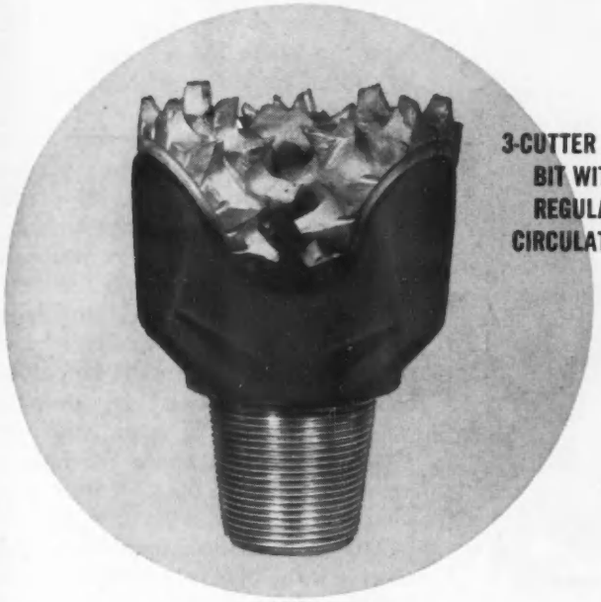
Mounting a winch on the headache rack for loading equipment too heavy for hand loading yet too small to require a winch truck will save men and time. By mounting the winch high, the load is given more li.t as it is pulled into the truck. The space on the truck

How-To-Do-It Ideas Earn Money, too!

WORLD OIL editors want how-to-do-it ideas, so your favorite short cut or invention could put money in your pocket! Write down the substance of your latest ideas and send them in with a picture or drawing of the installation . . . if accepted, $10 for each idea will be yours. Send those money-making ideas today to Hints Editor, WORLD OIL, P. O. Box 2608, Houston 1, Texas.

H C Smith 3-CUTTER ROCK BITS

every bit the best



3-CUTTER ROCK BIT WITH REGULAR CIRCULATION

3-CUTTER ROCK BIT WITH JET CIRCULATION (new threaded flow nozzles)

The BEST gives you *Economy* too!

When you figure economy in terms of results obtained per dollar spent, you'll find that H. C. Smith Rock Bits are right up front. For many drillers can tell you that they make more hole – faster and straighter – with H. C. Smith Bits.

There are good reasons why!

COMPACT BODY DESIGN gives H. C. Smith Bits greater clearance between bit and hole wall . . . more room for return circulation to sweep away bit cuttings. Bit teeth stay on bottom, making hole, not just grinding up cuttings. ***That's economy in time!***

ADVANCED ENGINEERING AND QUALITY-CONTROL – the finest in the industry, with steel to our own specifications – make H. C. Smith Bits the toughest and strongest you can buy. ***That's economy in long life!***

PROVEN EFFICIENCY – because all H. C. Smith Bit patterns are field-tested, field-proven in a wide variety of drilling conditions, before you ever get them. ***That's economy in operation!***

H. C. SMITH 3-CUTTER JET ROCK BITS ALSO FEATURE THE NEW REPLACEABLE THREADED FLOW NOZZLE – THE ONLY 3-CUTTER BITS TO PROVIDE THIS IMPORTANT OPERATING ADVANTAGE.

For long life, efficiency and freedom from trouble, you can't do better than H. C. Smith Rock Bits.

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bed can be used for the load, since the winch is out of the way.

The heavy frame of the headache rack is shopmade of 1½-inch pipe that extends down the wells on the truck bed corners. The winch mount is made of plate steel welded across the horizontal members of the rack. The braces from the side boards to the rack are triangular-shaped plate welded to the rack and bolted to the side of the truck, giving the rack more rigidity. The winch line and the rack will withstand about the same pull.

The assembly is at a convenient place. Location of the winch also moves the operator out of the way of the load during loading. This type of mounting leaves room for the other equipment usually mounted on the headache rack.

Observation Hole Allows Constant Look at Mud

Watching the mud returns can be a tedious chore for the drilling crew on drilling barges or offshore rigs that may not have a mud pit level indicator or where the mud system is located a good distance from the rig floor or on another deck. One contractor installed an "observation hole," shown in the picture, for convenience of the driller or floor hands.

This installation on a drilling barge where the rotary floor was directly over the shale shaker was made by cutting a hole into the floor directly over the shaker. A section of large conductor pipe was then set above the hole to prevent anyone on the floor from stepping into it.

The driller or floor hands can easily observe if the pipe is "swabbing" when coming out of the hole or if the hole is "filled up" when going into the hole. The driller can also easily keep a constant eye on the mud "coming around" when drilling.

Small Bridge Over Pipes Reduces Walking Hazards

The maze of pipes which make up the fluid system on a drilling rig often make walking hazardous. The small catwalk illustrated is one easy way of reducing this hazard where the traffic is heavy.

Made of angle iron and expanded metal, it fits into the pattern of pipe after the mud system has been erected.

The entire frame is of angle iron welded into a solid unit. The angle steps are backed with expanded metal

when the $64,000. QUESTION is MUD...

You'll win more than this prize. You'll increase drilling efficiency and control your mud better. Mud-O-Graf records every variation in mud weight, saving time and costly errors in the addition of weighting materials. All heavy and light streaks in the circulating system and their duration are recorded. Mud-O-Graf shows how often the hole is filled up when coming out of the hole and shows the time of a complete circulation. If it's a question of mud, ask for Mud-O-Graf.

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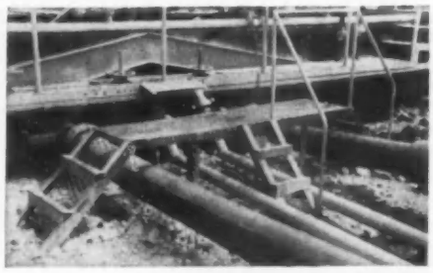
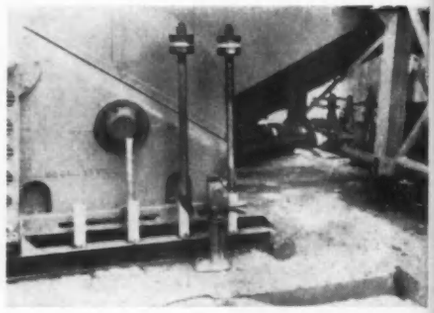


to keep your foot from slipping off under the platform. Hand rails are placed wherever necessary to assure safe passage.

To make this unit even more flexible it could be bolted together if the demands on its size are not constant for each job.

Use Scrap Pipe and Skid For Tool Storage Space

Piston shafts, jack handles and tools of this nature are not easy things for which to find a suitable place around a rig. Here is the way one operator solved the problem.



Short lengths of small O.D. pipe were welded to an H-beam skid as shown and the shafts inserted. The pipes can be of various diameters and lengths to allow for the storage of a variety of parts and tools.

To make them noticeable, the pipes are brightly painted. Small holes are drilled at the base of the pipes to allow rain or wash down water to drain out thereby reducing the possibility of corrosion.

Drill Collar Pick-Up Stand Helps Good Housekeeping

The simple, easily constructed stand illustrated above provides excellent storage space for drill collar pick-up subs.

Constructed from junk pipe, the stand can be built to handle any desired number of subs. A guide is welded to the lower cross bar so that the sub cannot slip from the rack. A split piece of pipe approximately 4 to 6 inches long is welded to the upper cross bar to provide a rest for the sub. This type of rack allows the subs to be picked up simply by attaching the catline and hoisting.

Besides providing convenient storage space, the stand is easily accessible, cheap to construct and promotes good housekeeping and safety.

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driltrol speeds the time from spud-in to production when changeable strata or directional drilling cuts you out of "easy pie" jobs.
(These drillable wing stabilizers can pay off in the soft stuff, too, because fast drilling can be maintained only when direction is controlled.)
With more weight on the bit, you get faster, *controlled* penetration. And, when necessary, washover is a matter of minutes!
More than 25,000 driltrol stabilizers have *speeded* drilling all over the globe; *controlled* drilling as fulcrums, hole straighteners, key seat guides, and preventatives for pressure differential sticking. Sizes to fit your job, priced at about half the cost of a single drill bit! For fastest drilling in anything but cream pie jobs, get the recipe from your driltrol man!

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Breakout torque set at any desired amount.

O-ring seals at both ends prevent corrosion of working parts.

NO Shear Pin. Joint may be re-set in the field in matter of seconds.

Spring loaded locking mechanism prevents joint accidentally jarring loose.

Simple and rugged.

"The Wrong Way"

Install in Sucker Rod string two or three rods above pump. If pump sticks, simply rotate rods to the left. Joint breaks at whatever torque is desired and backs off easily, leaving only the pump in the tubing. Tubing can then be pulled in the normal manner. May also be used as "on-and-off" tool.

Safe, Practical and Thoroughly Field Proven.

Priced so low that it is economical to run them in all pumping wells. One stripping job saved more than pays for the tool.

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PRODUCTION HINTS

These How-To-Do-It Ideas Can Save You Money

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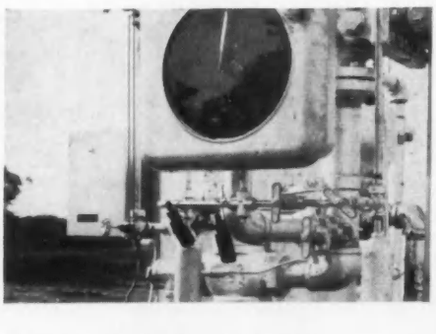
Mount Sheet Metal on Centrifuge Stand

Centrifuge mountings in the field may be seen in many forms. A very unique installation for mounting the centrifuge and at the same time providing protection for the centrifuge, holders and any other material that is normally required to determine the cut of oil or condensate is shown in the picture. The installation also serves as a table or platform to conveniently store the centrifuge shake-out tubes, solvent and sample containers.

The stand was made from two-inch pipe set in concrete below the surface. This section was welded to a piece of sheet metal supported by four scrap pieces of iron, welded in a 45-degree position from the table platform back to the main support riser. One section of the table platform is cut out to provide a mounting position for the recessed centrifuge. Hinges are welded to connect the rear of the table platform and metal cover. A handle, made from a scrap bolt, is then welded to the cover. The most convenient location to mount the centrifuge stand is normally near the wellhead.



Fasten Ink Bottles to Chart Metering Sites

An adequate and constant supply of ink can be assured at chart metering sites by anchoring the ink bottle with a short piece of wire. Wrap the wire around the neck of the bottle, below the cap so bottle can be opened and closed. Secure the other end of the wire around one of the small pipes leading into the chart.

Bottles secured in this manner are less likely to be broken or lost entirely. An occasional refilling of bottle insures an ever present supply of ink.

Drip Lubricator Made From 4-Inch Bull Plug

A drip lubricator for the drive-chain of a pulling unit can be made from a 4-inch bull plug. This will give a continuous lubrication to the chain and reduce the chances of the chain running dry. A 4-inch swedge nipple with a ¼-inch connection can be used to hold the oil. A sight feed glass is fitted to the bottom of the oil reservoir and a needle valve installed. The ¼-inch line is run from this to a point over the chain.

A support for the vessel is mad

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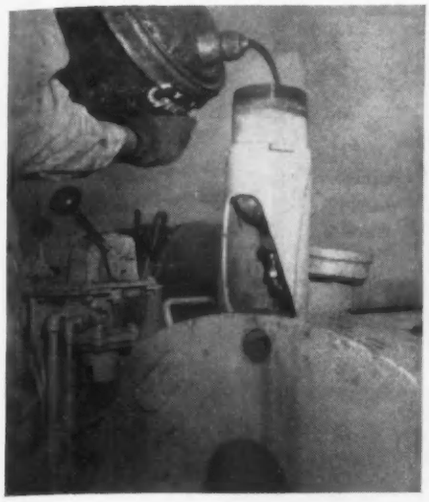

by cutting a window in the bottom and welding a 5 3/6-inch nipple to the top of the break drum on the winch. A slot is cut in the top of the nipple to match the ears welded to the side of the bull plug to hold it in place. This method of mounting allows easy removal of the chain before cleaning and the repair of the sight feed mechanism.

This type lubricator is inexpensive since most materials are available in the yard. The drip can be varied by the valve set below the oil reservoir.

Take Ground Level Samples From Sump Chamber Tank

A ground level tank sample collecting unit can be made so that samples can be taken at ground level from different levels in the tank.

The sampler consists of three or more outlets in the tank connected to a central point by piping using ½-inch pipes to bring the samples to the

"Pump more oil"

By the time you get a good test on this pump, it will probably have paid for itself!

For one oil company (name upon request) a Double-Displacement Rod Pump paid out before the test was even completed!

If your wells are beginning to pump too much water and you must move more fluid to make your allowable, or if you would like to quit pumping so hard so you can slow down your pumping units (thereby saving wear and tear on your equipment) — ask your store, or one of our representatives, about a Double-Displacement Rod Pump.

The Double-Displacement is a traveling barrel, bottom hold-down assembly made up of two plungers and two barrel tubes which work simultaneously with a single set of valves. In operation, the assembly produces as two separate pumps made up in tandem which virtually doubles the volume of the unit — as compared to the displacement of comparable-sized pumps. The Double-Displacement also has the additional operating advantages of an insert-type pump which can be run and pulled on the rods. Hundreds of these pumps are in daily operation throughout the Mid-Continent and Gulf Coast areas, including many water flood projects.

H-F Double-Displacement Rod Pumps are available in a wide range of metal-to-metal, H-F "Flexite,"® or soft packing plungers with chrome-plated or heat-treated barrel tubes in 2"x1½", 2½"x2", and 3"x2½" sizes.

If you think a Double-Displacement Pump might solve the production problems you have been having with your wells — talk to your store, one of our many factory representatives throughout the oil patch, or write to us at P. O. Box 127 in Fort Worth. We'll be glad to send you complete details, illustrated literature, and comparison data without obligation.

NOTE — *This is the original Double-Displacement Pump — marketed by Harbison-Fischer in 1950 . . . not to be confused with imitation pumps which do not measure up to the performance record that hundreds of Double-Displacement Pumps have always enjoyed throughout the oil patch. When you run a Double-Displacement Pump, be sure you get the genuine original.*

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"Best Pumps in the Oil Patch"®

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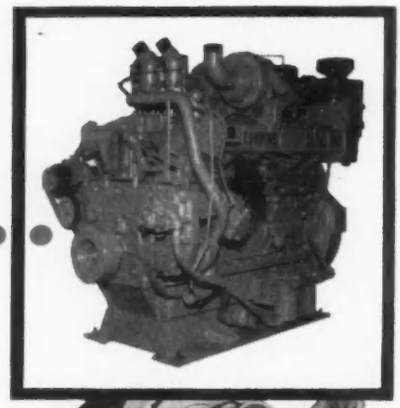
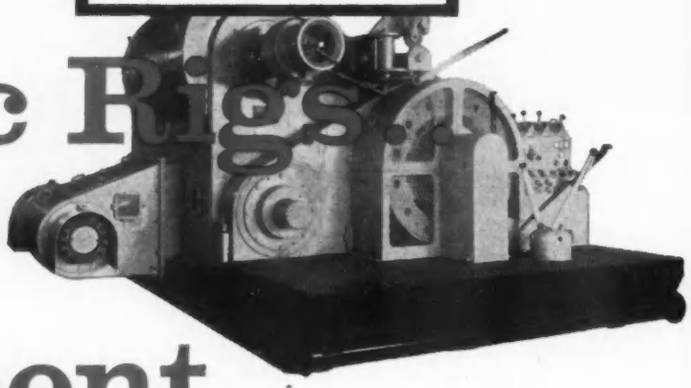
Engines...



Electric Rigs...



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sump unit. Old tank iron is used to make the sump, which is on a short standpipe connected to the pit, allowing the lines to be cleared before a sample is collected. The lines are drained directly into the sump.

Usually three levels are sufficient to insure a good sample collection from the tank. An outlet placed in the bottom, one about 6 feet from the bottom and one near the top enables the operator to open each line in its turn. Samples are collected from a definite point in the tank to determine the water content without thiefing the tanks. Sampling is therefore more convenient, and cost of the unit is low.

Vent Line Connection Keeps Gas From Leaking

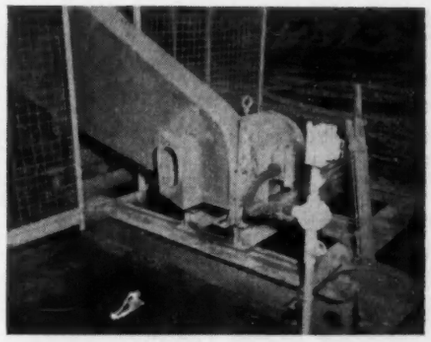
When a lease has depleted to the point where fuel gas is at a premium, a simple connection may be made on the vent line which will save any gas lost by leakage through double seated back pressure valves.

A plug valve is installed in the flare line riser. A ¾-inch by-pass line equipped with a pop valve is laid around the plug valve as shown. When placing in operation, the plug valve is closed and the back pressure valve propped wide open. The ¾-inch pop valve is set to relieve at a pressure slightly greater than lease needs, yet it will provide a tight seal during the time the lease is shut down or producing no gas.

If drilling or workover operations provide excess gas at a later date, the back pressure valve can be returned to service in a few minutes.

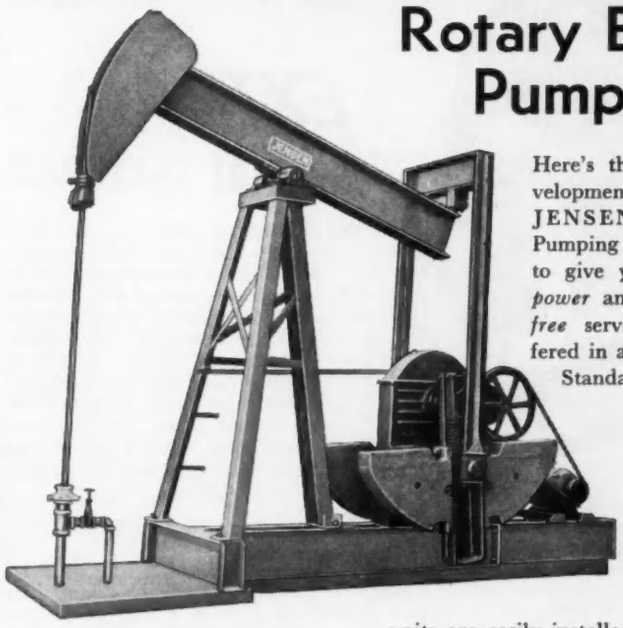
Guard Support Bracket Simplifies Pulley Changes

Changing motors or equipping the existing pumping unit motor with a larger or smaller diameter pulley often means that the V-belt guard must be raised or lowered to accommodate the changed drive. This may involve welding of new angle brackets or "feet" to the guard, also burning of new holes to accommodate shifted bolt positions. Since well conditions vary continually, this means the adjusting process may have to be repeated a number of times in the normal life of the well.



NEW FROM JENSEN

Rotary Balanced Pumping Jack

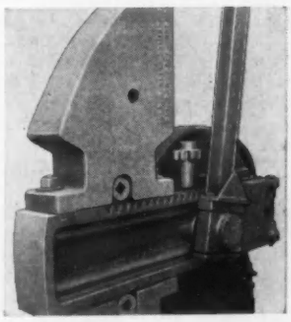


Here's the latest JENSEN development—the all new line of JENSEN Rotary Balanced Pumping Jacks—pre-engineered to give you *smoother lifting power* and *economical trouble-free* service. They're now offered in addition to the popular Standard Series.

These new units offer full crank balance and complete floor clearance. You eliminate the need for expensive foundations and crank weight wells. JENSEN units are easily installed on flat concrete surfaces or on simplified steel skids.

Larger and heavier main shafts and bearings . . . taller, more rigid Samson posts . . . easily adjusted counterbalance with extra weights . . . precision-cut single and double reduction gears . . . simplified lubrication system.

Send for your copy of our catalog, fully describing the new JENSEN Rotary Series. A call or letter will bring it to you—quick!



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Counterbalance can be adjusted—safely and easily—by one man standing on the ground. Unique JENSEN rack-and-pinion system assures speedy weight adjustments, gives both lead and lag.

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JENSEN JACKS

For more data on advertised products, use Readers' Service Cards, last page.

One operator saves considerable time and effort by equipping the unit with a shopmade bracket which allows rapid adjustment of the guard position when necessary. To the outer end of the motor rail is welded a bracket to which, in turn, is welded an upright piece of flat bar stock, the latter having a row of evenly spaced bolt holes drilled through it. Two horizontal slots at the proper level to match two of the bar holes, are burned through the guard.

With this installation, it becomes a simple matter to unbolt and raise or lower the guard and tighten the nuts. Having slots in the guard permits lateral adjustments of an inch or so either way to simplify getting sufficient side clearance for the belts.

Old Turnstile Will Convert Into Stand for Barrel

The barrel stand is an often needed item around the field and it is almost always necessary to construct one. This consumes time and materials as well as being a worry to the operator. If somewhere around the storage yard there is an old turnstile that is not being used for its intended purpose, the solution to your barrel stand needs is presented here.

Place the old turnstile in the desired spot for your barrel and you have a stand ready for the barrel. The barrel can be placed in the "V" formed by the two upright sides of the stile, while the two sides that are down form the legs that support the barrel. The pivot post of the stile becomes a handle. This will aid in emptying the barrel as it nears the completely empty mark.

In this way a good stand is not only gained, but it saves the time and material necessary for construction and eliminates also the necessity of storing the old stile. This stand is completely portable and can be moved and placed at any desired position or spot in the field.

With this type stand, one man can place the full barrel in the barrel stand. This is done by putting the old stile upside down on the ground and rolling a barrel up to it. Then turn the barrel upside down and put it in the "V" that will be upright when the stand is laid down. Then, by holding the barrel with one hand and taking the high end of the pivot post in the other, the barrel and stand can be leaned and put into place by using the old stile as a pry bar. This will place the barrel in position to be emptied when the stile is laid down.

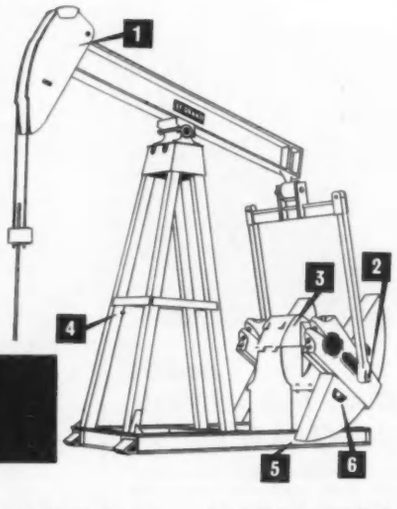
EXTRA
SPECIAL FEATURES

The more distinctive and original the facial adornments of this New Guinea tribesman the more important he becomes in the eyes of his fellows. The character illustrated is wearing the Australian Government's Service Medal on his brow, and the cap badge of a shot down airman in his cowrie headband. Many other adornments from wrecked Allied and Japanese aircraft are worn to give distinction to the owner.

Much more appreciated by oilmen in the field are the extra special features of the Le Grand Pumping Units which make them so rugged—dependable—reliable.

Note these outstanding features:

1. Swing back mulehead provides ample well clearance for well servicing. Mulehead retaining bolt operated from samson post.
2. Patented wrist pin for ease of changing stroke; no seizure occurs requiring hammering or burning out to remove.
3. Double reduction, double helical gears with anti-friction bearings throughout.
4. Inbuilt oil reservoirs provided in bearings with lubrication points at shoulder level throughout, using one grade of oil throughout.
5. All units have floor clearing cranks.
6. One man operated counterbalances in one horizontal setting of the cranks.



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VENEZUELA Eastern: A-Z Export, S.A., Apartado 4062, Puerto La Cruz, E. Venezuela
VENEZUELA Western: A-Z Export, S.A., Apartado 304, Maracaibo, W. Venezuela

WHO'S MEETING WHERE

JULY 18	Los Angeles Chapter of NOMADs Whing Ding. Long Beach, Calif., Lakewood Country Club.
JULY 31-AUG. 2	Rocky Mountain Mineral Law Foundation Institute 4th Annual Meeting, University of Colorado, Boulder, Colo.
SEPT 1-13	Internation Conference on the Peaceful Uses of Atomic Engery, Geneva, Switzerland.
7-11	World Power Conference, Montreal, Quebec, Queen Elizabeth Hotel.
10-12	National Petroleum Association, 56th Annual Meeting, Atlantic City, N. J., Traymore Hotel.
15-19	Instrument Society of America, 13th Annual Instrument-Automation Conference and Exhibit, Philadelphia, Penn.
21-24	AIME, Conference on Petroleum, Denver, Cosmopolitan Hotel.
25-26	Mid-Continent Oil & Gas Assn., La.-Ark. Division, Annual Meeting, New Orleans, Roosevelt Hotel.
OCT. 1- 3	AAODC, 18th Annual Meeting, Dallas, Adolphus and Baker Hotels.
5- 8	AIME, Society of Petroleum Engineers, Fall Meeting, Houston.
7-8	Texas Mid-Continent Oil & Gas Assn., 39th Annual Meeting, Dallas, Statler-Hilton Hotel.
12-18	OIL Progress Week.
13-15	AGA Annual Convention, Atlantic City, Site Unreported.
13-16	Society of Exploration Geophysicists, 28th Annual International Meeting, San Antonio, Gunter Hotel.
15-16	South Dakota Independent Oil Men's Assn., Convention, Rapid City, S. D., Sheraton-Johnson Hotel.
15-17	Second Energy Resources Conference, Denver, Brown Palace Hotel.
16-17	AIME, Southern California Petroleum Section Fall Meeting, Los Angeles, Biltmore Hotel.
16-19	1958 Permian Basin Oil Show, Odessa, Texas.
27-28	IPAA Annual Meeting, Dallas, Statler-Hilton.
NOV. 6-7	AAPG Pacific section, Annual Meeting, Los Angeles.
10-13	API 38th Annual Meeting, Chicago, Conrad Hilton, Palmer House and Congress Hotels.
DEC. 5	ASME, Annual Meeting, New York City, Statler & Sheraton-McAlpin Hotels.

Nomads' Chapter monthly meeting: Los Angeles, second Wednesday, Jonathan Club, Wallace A. Sawdon, Secretary. Houston, second Monday, Ye Old College Inn, Harry E. Estes, Secretary. Dallas-Fort Worth, first Monday, Greater Dallas Club, Hank Davis, Secretary. Tulsa, Hotel Tulsa, Gilbert Swift, Secretary. New York, first Monday, Hotel Biltmore, Jesse E. Hickman, Secretary.

What's Happening among MEN in the INDUSTRY

Clifford W. Peery has been named president of **Mene Grande Oil Co.**, Venezuela, succeeding **I. G. Davis** who recently was named vice president of Gulf Oil Corporation.

Dr. William Schriever, University of Oklahoma physics professor, has been conferred the first honorary membership in the Geophysical Society of Tulsa.

Standard Oil Company (Ohio) has elected three new directors. They are **T. Keith Glennan,** president of Case Institute of Technology, Cleveland; **Richard C. Sauer,** vice president—supply and distribution of Standard (Ohio), Cleveland; and **Sidney A. Swensrud,** former chairman of the board of Gulf Oil Corporation and earlier the executive vice president of Standard (Ohio).

Milton A. Lobree and **Hal S. Lobree,** midwestern oil finders, have moved into new offices in Evansville, Ind. These offices will combine the operation of **Lobree & Lobree,** a crude oil producing company. Milton A. Lobree is an independent oil producer, and Hal S. Lobree is an independent consulting geologist and oil producer.

C. Warren Hunt, geologist, and **D. Bruce McDougall,** geophysicist, announce the opening of their offices in Calgary, Alberta, Canada.

Kerr-McGee Oil Industries, Inc., has established a Foreign Exploration division under the direction of **J. C. Finley,** vice president. In addition, Finley is responsible for matters pertaining to acquisition of domestic properties. Exploration activities in the United States and Canada are now handled by Harold J. Kleen, formerly chief geologist, now exploration manager. Geological, Geophysical, Land and Lease Records departments report to Kleen. **John Masters** has been promoted to chief geologist, with all geological districts and divisions under his supervision. **L. W. Curtis** becomes assistant chief geologist. **Jere McKinney** has been promoted to district geologist with headquarters in Oklahoma City.

Parker Drilling Co. of Brazil has been formed to operate for the Brazilian Oil Company, Petrobras, the government oil monopoly. **Grover Colwell** and **R. N. Bynum** have been appointed vice president, and vice president and secretary, respectively of the new company. **R. M. New** will be area manager; **C. R. Stewart** will be general drilling superintendent, and **Bob Tillman** will be general mud engineer.

F. Lamar Loftis, formerly with Oilfield Sales & Service of Maracaibo, Venezuela, is now with the **Pure Oil Co. of Paraguay, Inc.,** as drilling superintendent.

A. W. Baucum

J. H. Rambin, Jr.

The Texas Company announced the election of **J. Howard Rambin, Jr.,** as senior vice president in charge of Texaco's worldwide producing interests and activities. He also announced the election of **A. W. Baucum** as vice president in charge of the Domestic Producing department, succeeding Rambin.

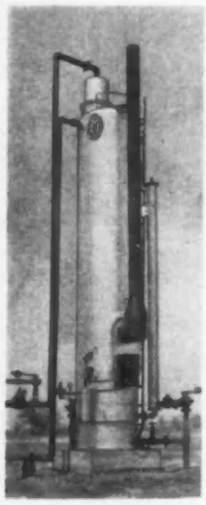
Jackson Martindell, chairman of the board of the American Institute of Management, New York City, has been elected a director of **Reiter-Foster Oil Corporation.**

J. G. Jimenez has been elected a vice president of **Tidewater Oil Company** and appointed general manager of the company's Eastern division operations. Formerly eastern division marketing manager, he replaces **George F. Getty II. John W. Gendron,** former administrative assistant to the president in San Francisco, was, at the same time, named assistant eastern division manager.

Drilling & Exploration Company, Inc., announced additions to its Geological department and the opening and consolidation of certain offices. **Jack E. Hughes,** who joined the company in March of 1957, has been appointed chief geologist. In order to consolidate operations in its Southwestern division, Drilexco has opened a geological and land office in Amarillo and closed its Abilene geological and Midland drilling offices. Affected by the transfer of the Midland office were **Floyd A. Nunley,** drilling superintendent, and **Eddie L. Hatfield,** clerk. Added to the company's Geological department in Amarillo was **John M. Mothershead,** formerly Amarillo district geologist for Ohio Oil Company. In Oklahoma City, and jointly with Mack Oil Company, Duncan, Okla., the company has opened a geological office under the direction of **Robert Harris.** Drilexco has also opened a geological office in Jackson, Miss., and has engaged **William J. Nugent** to head up the department there.

British American Oil Company Limited has announced the appointment of **E. J. Gallagher** as general manager of the Production and Pipe Line department with headquarters in Calgary. **O. I. Torkelsen,** vice president, will assume executive duties

For
OPERATING ECONOMY



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TANKS - TREATERS
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BAY CITY, TEXAS
J. P. Graham.....CI 5-4526
BEAUMONT, TEXAS
Assoc. Eng. & Eqpt., Inc....TE 5-7046, ZF 8-2038
CASPER, WYOMING
C. A. White.....3-5264
GLENDIVE, MONTANA
C. A. White.....EM 5-3638
HOBBS, NEW MEXICO
Horne Well Service Co.....3-5896
HOUSTON, TEXAS
Assoc. Eng. & Eqpt., Inc.....CA 5-1103
KILGORE, TEXAS
Davis-Kemp Tool Co., Inc.....5541
LAFAYETTE, LOUISIANA
Assoc. Eng. & Eqpt., Inc.....CE 5-6770
LIBERAL, KANSAS
Rainbo Service .....Main 4-3598
LINDSAY, OKLAHOMA
Rainbo Service Co.....539
MIDLAND, TEXAS
Lucoous Service & Eqpt. Co.....MU 2-1631
NEW ORLEANS, LOUISIANA
Assoc. Eng. & Eqpt., Inc.....VE 5-4082
OKLAHOMA CITY, OKLAHOMA
Rainbo Service Co.....ME 4-2131, ME 4-6105
WHITTIER, CALIFORNIA
Kline Wire Line Co.....OX 6-2781
WICHITA FALLS, TEXAS
Hudson-Eads, Inc. 2-3767, 2-8584, 3-4690

relating to production and pipe line operations with headquarters in Toronto.

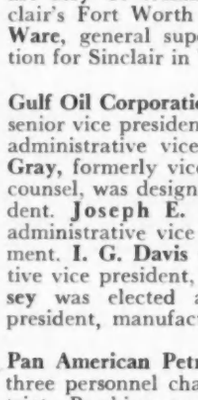
Birdwell, Inc., named **Stanley M. Flynn** vice president in charge of logging operations. Flynn joined Birdwell, Inc., in 1947. He is a veteran of more than 20 years oil and gas production and exploration experience.

Ohio Oil Company made some top-level changes. **B. B. Miller,** former superintendent of the company's Robinson, Ill., refinery, is the new assistant to the president. He succeeds **R. M. Churchwell,** who becomes manager of foreign operations, a newly created position. **G. R. Schoonmaker,** former assistant manager of foreign production, also steps into a new position, manager of foreign exploration. These men will be directly responsible to **Fred J. Funk,** manager of the Ohio Oil Company's foreign organization. Schoonmaker will be in charge of all oil and gas exploratory activities of Ohio Oil's Foreign Production Group. Churchwell will be in charge of foreign drilling, production and other development activities.

Sinclair Oil and Gas Company announced the election of two vice presidents. They are **Roy C. Williamson,** manager of Sinclair's Fort Worth division, and **Loren L. Ware,** general superintendent of exploration for Sinclair in Tulsa.

Gulf Oil Corporation has designated a new senior vice president and elected three new administrative vice presidents. **Archie D. Gray,** formerly vice president and general counsel, was designated a senior vice president. **Joseph E. Bounds** was elected administrative vice president, Tax department. **I. G. Davis** was elected administrative vice president, production. **B. R. Dorsey** was elected administrative vice president, manufacturing.

Pan American Petroleum Corp. has made three personnel changes in its Alberta district, Pembina area and Edmonton area production offices. **J. B. Oakley,** formerly assistant division engineer at Pan American's Canadian division office in Calgary, has been named district engineer at the firm's Alberta district. **H. W. Hinkle,** formerly district engineer at the Alberta district, has been appointed field superintendent at the Pan American Pembina area. **W. M. Bogert,** formerly field superintendent at the Pembina area, has been transferred to the Edmonton area, where he will be field superintendent.



Dr. W. W. Mallory

Dr. William Wyman Mallory has recently joined **Ball Associates,** oil and gas consultants of Denver and Washington, to specialize in exploration for oil and gas in the Rocky Mountain region. Dr. Mallory had been supervisor of stratigraphic projects in the Rocky Mountains for Phillips Petroleum Company for several years.

Dr. Charles G. Dodd is studying clay mineral surface chemistry, at the University of Oklahoma. He has undertaken the two-year research project under a $20,000 contract between the National Science Foundation and the OU Research Institute.

Sewart H. Folk has accepted a position as vice president of **T.U.L.M. Corporation,** consultants in foreign petroleum exploration and development for Tennessee Gas Transmission Company, Union Oil and Gas Corporation of Louisiana, Lion Oil Company and Murphy Corporation. Previously he had been vice president of Texas Gulf Sulphur Co. subsidiaries conducting mineral exploration in Italy and other countries of the eastern hemisphere.

David T. Staples

George F. Getty, II

David T. Staples was elected chairman of the board of directors of **Tidewater Oil Company.** Succeeding him as president is **George F. Getty, II,** who advances from his previous post as vice president and general manager of the company's Eastern division. Tidewater's new President entered the petroleum industry in 1947 as an independent oil operator.

R. E. Foss, H. O. Harder and **R. Paul Henry,** vice presidents for production, exploration and finance, respectively, for **Sunray Mid-Continent Oil Co.,** have been named to the firm's board of directors.

John M. Houchin, vice president and a director of **Phillips Petroleum Company,** was elected a member of the company's executive committee.

L. L. Aitken has been elected executive vice president of **Utah Southern Oil Company.** He is in direct charge of Utah Southern's exploration and production activities.

Herbert L. Peel, general production superintendent, The Vickers Petroleum Co., Inc., has resigned to accept a similar position with **Cheyenne Oil Corporation.** Peel became associated with Vickers Petroleum in 1950. **George A. Stovall,** head of reservoir engineering in Vickers' Production department, will assume duties and responsibilities formerly held by Peel in addition to his reservoir engineering duties. The new assignment will carry the title of chief engineer. Stovall has been associated with Vickers for almost two years.

Falcon Seaboard Drilling Co. announced the "Rig of the Year" annual safety award. The winning rig was supervised by **C. O. (Shorty) Pritchett,** and drillers **Halo Ramsey, D. J. Warden** and **Jack Rush.**

Marlin E. Sandlin has been elected executive vice president of **Woodley Petroleum Company,** and **E. David Philley** has been named general counsel. The company's other officers, all re-elected at the meeting, are **J. R. Parten,** president; **H. W.**

Davenport, vice president; **W. T. Moran**, vice president; **J. B. Cook**, vice president-treasurer; and J. W. Boothe, assistant secretary and assistant treasurer. Philley also was re-elected as secretary.

James S. Royds

George M. Sullivan

George M. Sullivan and **James S. Royds** have been elected administrative vice presidents of **Continental Oil Company.** Sullivan is general manager of marketing for Continental, while Royds is general manager of exploration, and each will continue to be responsible for these same functions.

Thomas O. Allen, senior supervising petroleum engineer with Humble Oil & Refining Company, left that company recently to become manager of the newly formed Drilling and Development division of **Jersey Production Research Company** in Tulsa. In his new position he will supervise an extensive program of research and development in the fields of drilling, logging and well completion.

E. J. Mulvihill, Jr., vice president of **Sinclair Venezuelan Oil Company,** 96.24 percent subsidiary of Sinclair Oil Corporation, has been elected to the board of directors of that company. Mulvihill joined Sinclair in 1941 in Venezuela and presently is the manager of its operations there.

J. Earle Gray has been assigned to full-time duties as manager of foreign operations of **Tidewater Oil Company.** Until recently Gray supervised foreign exploration and production operations in addition to his responsibilities as assistant general manager of the company's Western division.

P. C. Spencer has been appointed treasurer of the **Fifth World Petroleum Congress, Inc.** Spencer is chairman of the board of Sinclair Oil Corporation. He succeeds **B. B. Jennings** who relinquished the appointment on his retirement from Socony Mobil Oil Company of which he was chairman of the board.

Harold T. Byck has been named assistant to the vice president of **Shell Development Company's** Exploration and Production Research division in Houston. Byck, who has been technical assistant to the president of Shell Development Company in New York since 1953, joined Shell in 1936 as a research chemist at the company's Emeryville, Calif., research center.

Imperial Oil Limited directors re-elected the following officers: **J. R. White,** president; **W. O. Twaits,** executive vice president; **J. A. Cogan, J. K. Jamieson,** and **T. F. Moore,** vice presidents. Other directors are **C. E. Carson, L. D. Fraser, J. W. Hamilton, W. D. C. Mackenzie** and **G. L. Macpherson.** Officers re-appointed were **C. D. Crichton,** general secretary; **J. H. Spence,** comptroller; and **D. W. McGibbon,** treasurer. **J. F. Barrett,** Q. C., is general counsel.

International Petroleum Company Limited has announced the appointment of **Howard C. Kauffmann, Jr.,** as assistant manager of operations at Talara, Peru. Kauffmann is presently production coordinator in International's Executive office at Coral Gables, Fla.

The Atlantic Refining Company has announced the appointment of **A. B. (Boone) Macaulay** as manager of the Oklahoma-Kansas region of the firm's Domestic Crude Oil Production department. He has been serving as assistant to the vice president and general manager of domestic and foreign production since 1956.

The Texas Company announced the appointment of **Maury L. Nee** as assistant to Vice President **J. B. Christian,** who is in charge of Texaco's Trinidad operations. Nee joined Texaco in February, 1957, and has been an executive assistant in the company's Finance and Economics department.

George Darrow has joined **Wm. Ross Cabeen and Associates** as district manager of the new Wm. Ross Cabeen and Associates office in Billings, Mont. Darrow was previously manager for Northwest Petroleum, Inc., at Billings.

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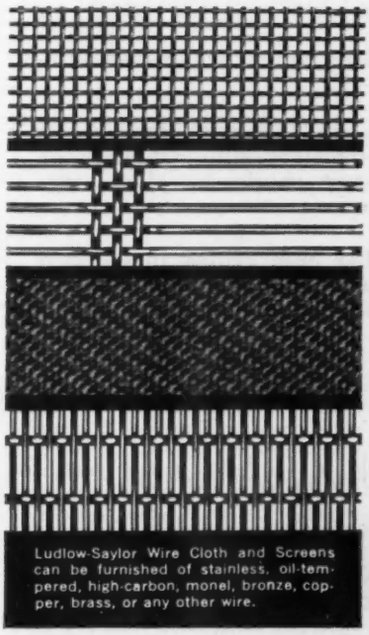

Ludlow-Saylor Wire Cloth and Screens can be furnished of stainless, oil-tempered, high-carbon, monel, bronze, copper, brass, or any other wire.

No guesswork here! To produce L-S crimping dies requires engineering knowledge of all physical and chemical characteristics of many kinds of wire, production know-how, skillful tool making plus critical supervision. Such careful methods are typical of Ludlow-Saylor manufacturing.

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For more data on advertised products, use Readers' Service Cards, last page.

A. Denys Cadman was appointed executive representative, New York City for **Gulf Oil Corporation.** Since 1952, Cadman has been industrial relations manager of The British American Oil Company Limited, Toronto, Canada.

George M. Buckingham, who started with the company 29 years ago, has been elected secretary of the **Esso Standard Oil Company.** Buckingham has been Esso's assistant secretary since 1945.

R. L. Packer, vice president, **Bell Petroleum Company,** has been elected president of the company. At the same time, **Frank B. Belcher** was elected vice president and general counsel, and **R. C. Linn,** comptroller, was elected secretary. Linn, together with **Orhan Salman,** manager of field operations, were elected to the board of directors. Other board members are **Alphonzo E. Bell, Belcher, Earl B. Gilmore, John B. Gostovich, Packer, Wellman P. Thayer** and **Marion C. Troster.**

Richard I. Galland has been named president of **American Petrofina Company of Texas,** operating division of American Petrofina, Inc. Galland, who will have offices in Dallas, will also serve as vice president and general counsel of American Petrofina, Inc. **J. M. Shea, Jr.,** and **Frank Durham,** have been named vice presidents of American Petrofina Company of Texas. Other officers of the operating division are **D. R. Zachry, Sr.,** executive vice president, and **Verne H. Maxwell,** vice president and general counsel.

Clifford R. Williams has been appointed chief engineer of the **Brewster Company.**

Dale Mount Drilling, Inc., has acquired the drilling tools and assets of Harry Bass Drilling Company and established home offices in Dallas. Principals in the new drilling contracting firm are **E. Dale Mount,** president, and **R. D. Jocoy,** vice president, who will head the Permian Basin office in Midland. **Dale Mount, Jr.,** will also be associated in the new company. The firm was founded in 1923 as Champlin & Bass.

E. Dale Mount

Dean A. McGee, president, Kerr-McGee Oil Industries, Inc., has been elected a director of the Chicago, Rock Island and Pacific Railroad Co.

Allan B. Erwin, formerly with Gulf Oil Corp., in Evansville, Ind., has joined the petroleum engineering staff of **Apache Oil Corporation.**

The Atlantic Refining Company has announced the appointment of **O. C. Clifford, Jr.,** to the newly created position of manager of the Foreign Crude Oil Exploration division. He was formerly chief geophysicist for the company's Domestic Exploration division. **C. H. Hightower,** who has been serving as assistant chief geophysicist since 1949 will succeed Clifford in his former position.

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DEATHS

Homer R. Pierce, 68, retired consulting engineer and former chairman of the ASME in Tulsa, died April 21. During his career he had been with South Penn Oil Co. and later formed the Oil and Gas Recovery Co. which specialized in secondary recovery operations in the Appalachian area.

S. R. Bailey, chief geologist, Mohawk Petroleum Corporation, Bakersfield, Calif., was killed April 21 when the Los Angeles to Denver airliner on which he was a passenger collided in mid-air over Las Vegas with a jet trainer.

Fred H. Rock, 62, independent oil operator, died April 28.

Benjamin Laughery, 73, retired division superintendent for the Phillips Petroleum Co., died May 3.

Parker Haight, 70, independent oil operator, died May 7 in a Houston hospital.

P. L. Tremblay, 49, eastern division manager of Shell Oil Company of Canada, Limited, died April 29.

Donald M. Clark, 37, petroleum engineer with Drilling Specialties Co., a subsidiary of Phillips Petroleum Co., died May 11.

Carl R. Hines, 63, independent oil operator, died May 11 in a Wichita, Kan., hospital.

Robert Fox MacArthur, 85, retired Tulsa oil operator and former vice president and general manager of the old Barnsdall Oil Co., died May 18.

New York Invitation Dinner

The New York chapter of NOMADs held its annual invitation dinner recently. There were approximately 260 NOMADs and guests which represents one of the largest attendances at an invitation dinner. Principal speaker of the evening was W. C. Sharp, assistant secretary of the Air Force. Seated left to right are Fred C. Sealey, America Overseas Petroleum Ltd., Maurice F. Delano, Jr., R. S. Stokvis & Sons, Inc.; Don E. Kircher, Gardner-Denver Co.; Sharp; E. E. Andreason, Andreason-Lundberg Corp.; and James A. Clark, Standard Oil Co. of New Jersey. Standing left to right are J. W. Chanda, A. O. Smith Corp.; D. T. O'Connor of D. T. O'Connor; W. E. Volkman, Cardwell Mfg. Co.; and Herb E. Maland, R. J. Eiche & Associates, Inc.

Houston NOMADs Hear Dr. Croneis

Dr. Corey Croneis, Provost of Rice Institute and head of the Geology department, took Houston NOMADs on a 4,000-mile boat trip up the Amazon via slides, and pointed out the oil installations and oil possibilities of the Amazon Basin. Tom W. Nelson, vice president and general manager of Gulf Publishing Co., publishers of WORLD OIL, introduced the speaker. International guests pictured above are (left to right—front row) Jacques Brisac, Cie Francaise des Petroles, d'Algerie; Norbert E. Rieter, Jr., Reed Roller Bit Co., Libya; James Bayliss, manufacturers representative, Brisbane, Australia; (back row) Lucien Taneux, Cie Francaise, d'Algerie; Frank Allinson, Cie Francaise, d'Algerie; Claude Barberot, S. N. Marep, Paris; Raymond Parre, S. N. Marep; and Martin Mears, Tidewater Oil Co., San Francisco.

Locke Succeeds O'Brien As TIPRO President

Eugene M. Locke, a partner in the law firm of Locke, Locke and Purnell and a director of Magna Oil and Dallas Tank Company, was elected president of the Texas Independent Producers and Royalty Owners Association at the organization's twelfth annual meeting.

Raymond D. Reynolds, Houston geologist and independent oil producer, was elected secretary, and Vance Foster, vice president of the First National Bank in Dallas, was re-elected treasurer. Executive Committee members and directors for districts throughout Texas were also elected.

Locke succeeded Jerome J. O'Brien who was presented a plaque honoring him for his service as president of the association.

W. E. Heater to Head Eastern Section of AAPG

The Eastern section of the American Association of Petroleum Geologists elected the following officers for the year 1958-59 during a recent meeting in New York City: W. E. Heater, American Overseas Petroleum Ltd., president; Ben F. Uhl, Conorada Petroleum Corporation, vice president; Richard C. Hasson, Arabian American Oil Company, secretary; and Mrs. Marion R. de Escallon, American Overseas Petroleum Ltd., treasurer.

API Forms Committee For Public Affairs

Membership of a new Committee on Public Affairs was announced by Frank M. Porter, president of the American Petroleum Institute. Formation of the committee was authorized by the Institute's board of directors last November, as part of its long-range plan to consolidate public and governmental relations activities.

It is anticipated that the new committee will be in a position to take over the activities of the American Petroleum Industries Committee and the Oil Information Committee by September 1, at which time the later groups will be dissolved.

what's Happening among INDUSTRY ASSOCIATIONS

New Rocky Mountain district officers elected for the API Production division are left to right: L. A. Lindstrom, C. J. Christensen, Freeman Egolf, George Goodin and W. G. Cutler.

Rocky Mountain API Picks Christensen as Chairman

C. J. Christensen, Pan American Petroleum Corp., Casper, Wyo., was elected new district chairman of the American Petroleum Institute's Rocky Mountain district, Division of Production. Christensen succeeds George Goodin, Petroleum Information, also of Casper. Goodin was named chairman of the district advisory committee for the coming year.

Claude Peavy, Britalta Petroleums, Ltd., Calgary, was elected vice chairman for Canada. New vice chairman for Wyoming is Freeman Egolf, Phillips Petroleum, Casper. Roy Fuller, Williston, N. D., was elected vice chairman for his state, and Clyde McCarty, Flint Rig Company, Billings, is new vice chairman for Montana.

Sam Letteer, Gulf Oil Corporation, Denver, is the vice chairman for Colorado and L. A. Lindstrom, Ohio Oil Co., Sidney, was named the corresponding position for Nebraska. W. G. Cutler, Pacific Northwest Pipe Line, Salt Lake City, was named vice chairman for Utah.

Bill McCullough, McCullough Tool Company, Casper, was elected secretary-treasurer of the district.

IPE Invites Delegates From 50 Oil Countries

Ambassadors of over 50 oil producing countries of the world have been extended personal invitations for their country to send official delegates to the May 14-23, 1959, International Petroleum Exposition in Tulsa, according to W. K. Warren, president of the IPE.

"In view of the IPE and World Petroleum Congress setting dates to allow foreign visitors to attend both at the same visit, and in view of the increasing world oil production, we expect attendance from other countries to triple at the 1959 IPE," Warren said.

Texas Tech API Scholarship Presentation

Walter D. Warren, engineering undergraduate of Meadow, Texas, (seated, right) is shown receiving a $500 scholarship award from R. P. Brouthertin, chairman of the South Plains chapter of the American Petroleum Institute. Standing, second from left, is Tech's assistant dean of engineering, Robert L. Newell. Others, left to right, are Coleman Williams, Jim Jordan and Jim Mayes, all members of the API Scholarship Committee which selected Warren as recipient of the 1958-1959 award.

Eastern Production of API Pick Chairmen for 1958

Robert S. Stewart, of Huntley and Huntley oil producers, has been elected chairman of the Eastern district of the American Petroleum Institute's Production division.

Vice chairmen elected at the meeting were: L. T. Evans, East Ohio Gas Co., North Canton, Ohio; Millard Flood, Ohio Oil Co., Terre Haute, Ind.; J. Robert Hornor, Delaware Gas Co., Clarksburg, W. Va.; H. J. Magner, Delta Drilling Co., Pittsburgh; Wendell Moore, Columbian Carbon Co., Charleston, W. Va.; Quentin Wood, Quaker State Refining Co., Bradford, Penn.; V. F. Sargent, Michigan Department of Conservation, Mt. Pleasant, Mich.; H. T. Hauple, Manufacturer's Light & Heat Co., Pittsburgh; Elmer Milz, Shell Oil Co., Centralia, Ill.

Earl Linn, Hiawatha Oil & Gas Co., Pittsburgh, is the new secretary-treasurer, and Lysle R. Kirk, Ohio Fuel Gas Co., Columbus, is chairman of the Eastern district Advisory Committee.

Houston Petroleum Club Names Bagby as Prexy

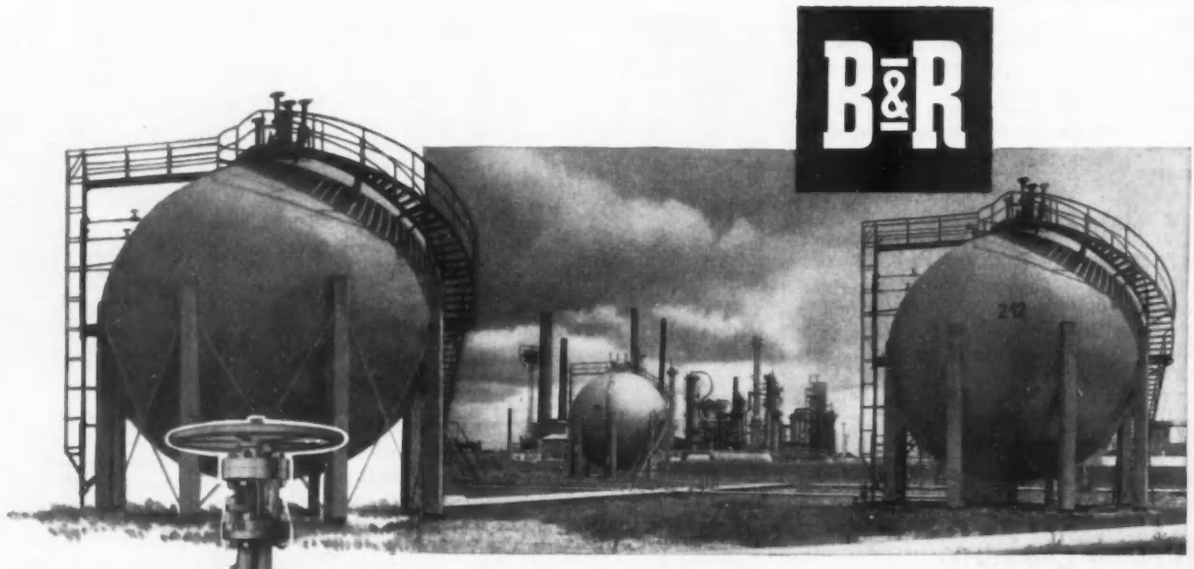
Houston independent oil producer Logan H. Bagby, Jr., was elected president of the Petroleum Club of Houston.

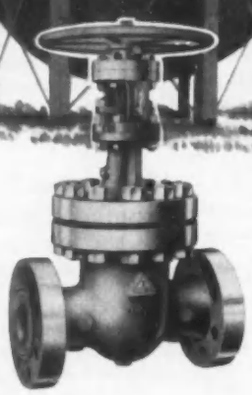
Four new directors were elected to serve until 1961. The directors met the following day to elect officers.

Chosen to serve with Bagby are A. L. Selig, first vice president; George C. Hardin, Jr., second vice president; Michael V. Kelly, secretary; H. M. Sewdler, treasurer; and H. F. Beardmore, assistant secretary-treasurer.

Kelly, Seydler and Beardmore are newly elected directors. The other is R. R. Dean. They will serve three year terms and succeed Sidney A. Adger, Col. W. B. Bates, J. R. Butler, and B. G. Martin. Butler is the retiring president.

Continuing on the board are Bagby, Hardin, Selig, E. Clyde McGraw, R. R. McLachlen, Walter G. Sterling and Howard C. Warren.





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Oil refineries

in many countries successfully equipped their modern plants with B&R Gate Valves, Globe Valves, Swing Check Valves, Safety Valves. B&R Valves are manufactured according to API specifications. Flange dimensions conform to ASA. Materials correspond to ASTM. One trial with our Valves will make you our customer for ever. Please ask for B&R catalog We 110e with detailed particulars on our lines of **oilfield and refinery equipment.**

BOPP & REUTHER G·M·B·H MANNHEIM - WALDHOF

What's Happening among SERVICE and SUPPLY MEN

Dayton Rubber Company made some changes in its Mechanical Goods division. **Millard D. Coate** was named manager of customer service and **Lester J. Adams** appointed merchandise manager for the division. Coate, formerly responsible for sales service, will have charge of sales correspondence, order, billing, production scheduling and Inventory Control departments. Adams, former administrative assistant, will be responsible for new products, improvement in present products, quality standards, basic merchandising and pricing.

Continental-Emsco Company announced the following changes in the Export division and the appointment of a new D+B Specialist in Borger, Texas. **Joseph F. Harris** was named D+B Specialist at the oil field manufacturer and supply company's Borger, Texas, store. Harris formerly was a sales representative at this point. Export changes include **George P. Daley,** former sales representative headquartering in Buenos Aires, Argentina, to export sales representative in the New York home office. The Houston Export office has appointed **George A. Stout** as supervisor of export traffic and purchasing.

Reynaldo C. Gonzales has been appointed field salesman for Continental-Emsco's store at Las Morochas, Venezuela. Gonzales was formerly stationed in New York.

Homer Doughty, Jr.

Fred Sexton

Wilson Supply Company has announced two recent appointments. **Homer Doughty, Jr.,** formerly a field salesman out of the Wilson Supply store at Victoria, Texas, has been transferred to the Midland, Texas, sales office of the company. **Fred Sexton** has been appointed manager of a new store at Monahans, Texas. He goes to Monahans from Hobbs, N. M., where he has been a field salesman.

John A. Ellis has been appointed sales manager of **Southern Pipe & Casing Co.,** Azusa, Calif., a division of U. S. Industries, Inc. Ellis, who has been with Southern Pipe since 1947, was moved up from assistant sales manager to fill the post vacated by **D. N. Chamberlain** recently promoted to executive vice president.

Drilling & Exploration Company, Inc., increased its slate of directors from 10 to 12. Both new members elected are vice presidents of Drilexco. They are **Robert L. Rose and Guy R. Brainard, Jr.**

L. K. Covelle, Jr., and **J. C. Delaplain** will assume new duties and responsibilities in an overseas expansion program now underway at **Willys-Overland Export Corporation**. Covelle, who has been administrative assistant to S. A. Girard, president since 1954, and who was elected a vice president of the export corporation a year ago, has been named vice president and general manager of the subsidiary. Delaplain has been appointed senior vice president in charge of overseas manufacturing and marketing development.

Alexander E. Walker has retired as chairman of the board of **The National Supply Company** after 19 years of activity with the company. He will serve in a consulting capacity with National.

Earl Carpenter, veteran of 14 years experience in oil field supply sales and store management, has joined the sales staff of **W. C. Norris,** Manufacturer, Division of Dover Corporation. Carpenter will work in Oklahoma and Kansas under **Jack Getty,** division manager, and will headquarter in Tulsa.

Richard A. Arnett was appointed marketing manager of the Industrial Instrumentation division of **Texas Instruments Incorporated.** Arnett joined Texas Instruments in 1954 and formerly was manager of IID's Industrial Engineering department. As marketing manager, he will direct both domestic and foreign marketing functions of the division.

B. J. Terrell has been named chief engineer for **Baash-Ross Division of Joy Manufacturing Company.** Terrell will be located at the company's Houston headquarters' office and will be in charge of the Engineering departments of the Houston and Long Beach plants, and will supervise product design, and the New Product Research and Development program.

Oil Metering and Processing Equipment Corporation has announced the appointment of **Jimmy L. Wyche** as sales engineer for the Rocky Mountain area. He will be located in Casper, Wyo.

Henry A. Ruysser, Jr., executive vice president of **Black, Sivalls & Bryson, Inc.,** was elected president of the Oilfield Tank Manufacturers Association at a recent meeting of the association in McAllen, Texas.

Layne & Bowler, Inc., elected **Edward J. Rogers,** president and general manager of Layne-Northwest Company, chairman of the board. The Board elected **C. E. Ponkey,** executive vice president.

Ralph Simpson, formerly assistant sales manager of **Whitmor Homebuilders** of Tulsa, has been promoted to a newly-created post of sales manager. **E. R. Blair, Jr.,** has been serving in the double capacity of production manager and sales manager. He will continue as production manager.

Z. C. R. Hansen

J. P. Dragin

The White Motor Company board of directors elected three of its executives to new positions. **Z. C. R. Hansen,** president of the Diamond T Motor Truck Co., of Chicago, a wholly-owned White subsidiary, was elected a director of White Co. He was also named executive vice president and general manager of the Diamond T division. **J. P. Dragin,** vice president-finance, was named executive vice president—finance and administration. He is a director of the company. He has been with White since 1945 and vice president since 1956. **William F. Burrows,** general manager of the White Diesel Engine division, was appointed vice president and general manager—Diesel Engine division.

W. F. Burrows

J. R. Blaisdell

J. R. Blaisdell was promoted to assistant vice president of **Seismograph Service Corp.,** and **S. W. Fruehling** to vice president of SSC (International). Blaisdell is personnel manager for SSC, with headquarters in Tulsa. Fruehling is manager of the firm's operations in Brazil, with headquarters in Rio de Janeiro.

C. B. McDonald was appointed regional special sales representative assigned to servicing specific drilling problems in the Gulf Coast regions of the United States, Central and South America for Security Engineering's Division, U. S. Industries. McDonald's tenure of service to the oil industry throughout North and South America covers some 30 years. He has been employed both by oil producing and

petroleum equipment companies. For years he operated his own bit and tool firm.

W. Samuel Carpenter, III, director of sales of **Du Pont's** Petroleum Chemicals division, became assistant general manager of the company's Electrochemicals department. He succeeds **Charles B. McCoy** who has been named general manager of the Elastomer Chemicals department.

Jones & Laughlin Steel Corporation announced two new appointments in its Tubular Products division. **Joe B. Gibson,** formerly special representative—line pipe products, has been promoted to assistant manager, tubular products. **William F. Ewart** has been promoted to administrative assistant—tubular products. Ewart formerly was a junior salesman in J&L's Baltimore, Md., Sales office.

United Geophysical Corporation announced the following changes in its officers and directorate. **C. C. Lister,** president of the corporation since 1953, has retired as an officer and director. While Lister is retiring from the active direction of the affairs of the organization, he will be available to devote part of his time and effort to United as an independent consultant on operations. **E. A. Pielemeier** was elected chairman of the board and **B. W. Sorge,** president of the United Geophysical companies. **R. G. Sohlberg** was elected president of United Electro Dynamics, Inc. Re-elected as vice presidents and directors of the corporation were **L. A. Martin, Dr. R. A. Peterson** and Sohlberg. **M. G. Noble** was re-elected secretary-treasurer and director, while **F. H. Agee** was added to the directorate to fill the vacancy caused by Lister's resignation.

BRITISH H/E MADE

300 P.A. TRACTOR DRILLMASTER

MULTI-PURPOSE · HIGHLY MOBILE

The Hands-England Drillmaster 300 P.A. Rotary Drill is now available mounted on a Fordson Major Tractor and is illustrated on left.

This design provides great manoeuvrability and is intended primarily to enable the well known H/E Drillmaster 300 P.A. Rotary Drill to be used for Quarry and Open Cast blast or shot holes.

Although the H/E Drillmaster 300 P.A. mounted on a diesel engined tractor, is ideal for Quarry and Open Cast operations, it is equally applicable to some difficult "off the road" locations, such as may be encountered during seismic exploration particularly in highly cultivated areas.

An air compressor giving 99 C F M can be mounted directly onto the drill subframe and driven from the tractor engine. This compressor gives an up-hole annular velocity of 3,000 ft./min. when using flush jointed drill pipe and holes of the following sizes:

1⅝" o/d. Drill Pipe	2⅞" dia. hole	
1.29/32" "	"	3⅛" " "
2⅜" "	"	3⅜" " "
2⅞" "	"	3¾" " "

Larger holes or holes drilled with mud circulation can of course be drilled, but the equipment for these operations must be mounted on a separate trailer or tractor.

The H/E Tractor Drillmaster will be found to cover the majority of drilling requirements of the Quarry and Open Cast operator, the Geologist, the Mineralogist, and the Geophysicist.

Write for illustrated folders giving full details and specifications of this equipment.

HANDS-ENGLAND OILFIELD EQUIPMENT LTD

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McCollum Receives Award

Burton McCollum (right) pioneer petroleum geophysicist of Houston, receives a citation for distinguished service from Chancellor Franklin D. Murphy of the University of Kansas. The award was among five conferred recently upon alumni of the University in Lawrence, Kan. McCollum is president of McCollum Exploration Co. and of McCollum Laboratories, Inc. One of the originators of geophysical prospecting, he was first to make practical application of the reflection seismograph in the oil industry. In World War I he was associated in battlefield development of sound-ranging equipment.

Rogers Geophysical Doubles Headquarters Plant Facilities

Rogers Geophysical Company has completed an expansion program at its Houston headquarters, which doubles square footage available for administration, laboratory and equipment assembly.

The new wing, which includes patios and fish pools, contains executive offices, a conference room, seven instrument research rooms, coffee bar, secretarial area, tripled drafting room facilities, a storage vault, printing room and mechanical room. The latter three are in a basement which was included in the expansion program.

Sperry-Western Inc. Triples Former Houston Location

Sperry Western, Inc., non-destructive testing service is now in new and larger quarters in Houston. The new home, consisting of a 4,000 sq. ft. laboratory and test building, and 1,200 sq. ft. office building, is about three times larger than their former location.

The company has installed ultra-sonic immersion equipment for conducting laboratory tests for detecting defects in various types of oil industry equipment.

Dowell Incorporated to Become Division of Dow Chemical

Dowell Incorporated, a wholly owned subsidiary of The Dow Chemical Company, became a division of Dow recently. There will be no changes in the present management of the new division, and all operations of the large service organization will continue to be directed from the general offices in Tulsa.

It is planned that the company's long established operations in Canada will be handled through a new Dow subsidiary. Dowell's Latin American subsidiary, United Oilwell Service, S. A. will also become a Dow subsidiary. Both companies report through the new Dowell division.

Soon to be replaced by a new 350-meter high tower, this 120-meter tower stands at the German Industry Fair.

Mannesmann to Replace Tower At German Fair With New One

Mannesmann erected in 1954 at the German Industry Fair at Hannover, a tower made of tubes (steel structure) of 120 meters height. In spite of its height it only weighed 35 tons; thus it became a landmark of the Fair.

The firm now plans setting up a tower of steel tubes of 350 meters height; preliminary work was started for quite a long time. The new tower is to be erected on the grounds of the Fair, the structure to consist of seamless steel tubing of Mannesmann manufacture.

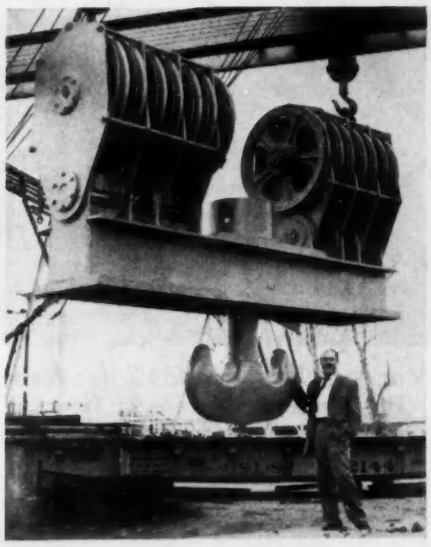
As may be gathered from the outline of this tower shown by the model its main features are determined by parabolic corner strut tubing. The weight of the tube construction will amount to about 350 tons.

Harold Brown Co. Designates Shaffer Tool as Representative

Shaffer Tool Works, with headquarters in Brea, Calif., has been appointed exclusive distributor for the Harold Brown Company's line of production equipment in California, Wyoming, North Dakota and Colorado.

Western Co. Adds Acidizing To Four Corners Services

Expansion of the Western Company's Cortez, Okla., district facilities to provide acidizing service for the Four Corners area has been announced. Acidizing service was added to already existing facilities for radioactivity logging, jet perforating and fracture initiation service at the Cortez station. The wire line services have been offered from the station since early January, 1958. William H. Dennis will continue as district manager of the combined pumping services-wire line operations at Cortez. Ben Hays, sales engineer, will represent Western in both services at Farmington, N. M.



Underwater Block

McKissick Products Corporation designed and produced one of the largest blocks ever built—a 40,000 pound Behemoth custom built. This mammoth block is designed for underwater use to lift gates on the St. Lawrence Seaway. It is equipped with completely sealed double row Timken bearings throughout. The duplex hook is hammer forged from high alloy steel and weighs 7,000 pounds. It will be reeved with 28 1⅜-inch diameter lines.

Workmanship
Reliability
Experience

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Macco Oil Tool Holds Sales Meeting

The annual sales meeting of Macco Oil Tool Co., Inc., was held recently at the plant and offices of the company in Houston. Pictured here are the representatives who attended, as follows: (Front row, left to right) R. P. Kirk, Odessa, Texas; Doug Clairbourne, Shreveport, La.; Oris Orton, Alice, Texas; Harry Ellington, Shreveport; Jean Deligans, Houma, La.; W. C. Carlisle, president; J. H. McCarvell, vice president; R. Z. Mendenhall, sales manager; Red Motes, Shreveport; J. D. Kent, Houston; H. D. Brewer, Houston. (Back row, left to right) Bill Deligans, Houma; Max Threadgill, Houston; Cliff Greene, Houston; Ward Haggard, Beaumont, Texas; John Witherspoon, Victoria, Texas; Joe Rosett, Shreveport; Don Witherspoon, Victoria; Al Fischer, Oklahoma City; Flint Berlin, Corpus Christi, Texas; Billy Grau, Shreveport; Ed Crowell, Houston; Buddy LaFour, Houston; Tommy Atkins, Houston. Not pictured and unable to attend were R. B. Tatum, New Iberia, La.; Larry Darling, Canada; Marty Zierer, California; Hugh Gransaull, Trinidad; and Dan Waters, Venezuela.

There is more than meets the eye in...

ACME DRILLING JARS

Carbon or Alloy Steel

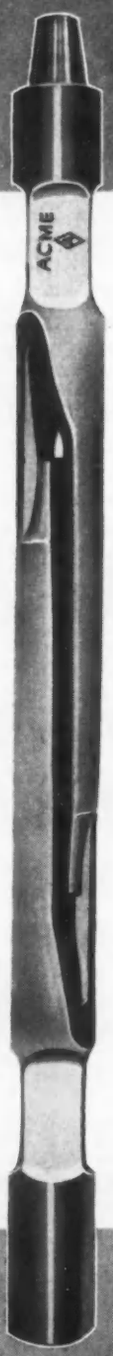
You can't see the higher quality steels and the controlled heat treating procedures that help make Acme jars last longer. Nor can you see the experience and integrity that stand behind these Acme products.

But you can see the Acme trademark—the stamp that means these jars have passed many exacting tests of quality control.

Acme offers two types of drilling jars—CARBON STEEL, first choice with many drillers and ALLOY STEEL, for extra footage and longer life.

Both type jars are warranted for a specific amount of wear—NO time limitation on the warranty.

Sold through dealers everywhere



ACME FISHING TOOL CO.
Box 860 — Dept. 10
PARKERSBURG, WEST VIRGINIA

Murdock Tank and Mfr. Forms Division for Packaged Units

Murdock Tank and Manufacturing Company of Tulsa and Odessa, has announced the formation of the Custody Transfer Systems division.

Murdock's new division manufactures complete automatic custody transfer systems for the automatic unattended sale of merchantable measured oil. These systems include both the calibrated positive meter tank and the positive displacement meter types. All are packaged units requiring field hook-up only.

Jones & Laughlin Announces District Sales Managers

Jones & Laughlin Supply Division announces two appointments in its Sales division. A. G. Wehrley has been promoted to district sales manager of the East Texas district with headquarters at Longview, Texas. V. H. Weldon, Jr., was named manager of the Canadian Region with headquarters at Calgary, Alberta.

Wehrley succeeds M. L. Eubank who recently retired. He has been with Jones & Laughlin since 1947 and was made assistant manager of East Texas district in 1953.

Weldon joined the company in 1946 and served as assistant manager of Canadian Operations prior to his promotion.

Dowell Transfers Personnel to New Rock Springs Station

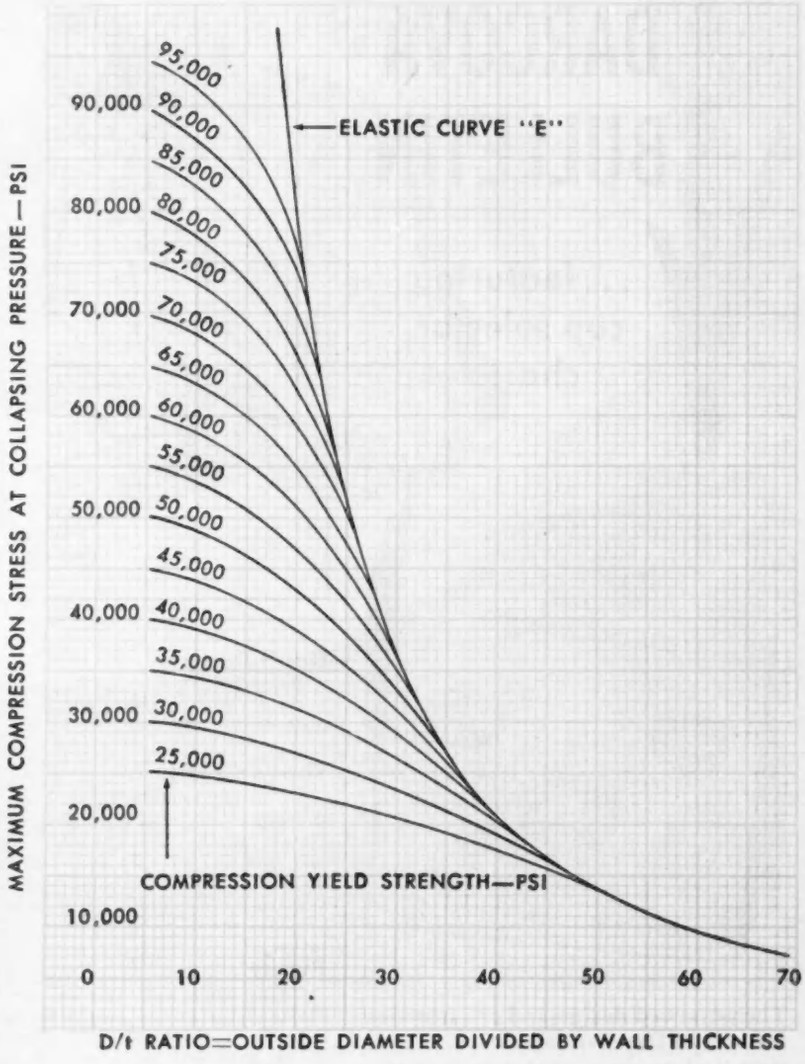
Dowell Incorporated, oil well and industrial servicing company, has opened a new station at Rock Springs, Wyo.

Personnel who have been transferred to Rock Springs include Dick Pampe, A. J. Ruttinger, Roland A. Ablett, R. J. Pickerel, R. L. Goff and L. E. Sullivan.

S-95 CASING

BASIC RESEARCH—The Jasper curves for collapse stress, shown on the right, are the basis for the published minimum collapse values for A. O. Smith casing.

DESIGN—(below) A. O. Smith uses its electronic computer as a modern tool in establishing sound and accurate casing string design.



A. O. Smith line pipe has always been manufactured to a high standard of quality for almost 30 years . . . precisely controlled at every step of production. That's why A. O. Smith pipe, made and installed in 1928, is still in operation. That's why so much A. O. Smith pipe is in nearly every important high-pressure line.

Through research . . . a better way

A.O.Smith

CORPORATION

TUBULAR PRODUCTS DIVISION

Milwaukee 1, Wisconsin

Chicago 4 • Dallas 35 • Houston 2 • Los Angeles 17
Midland 5, Texas • New Orleans 12 • New York 17 • Tulsa 3
A. O. Smith International S. A., Milwaukee 1, Wisconsin, U. S. A.

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The advanced design and construction features of Darcova valve cups, seating cups and rings offer unmatched performance, efficiency and economy! With a full range of precision sizes and texture-engineered compositions to choose from you can *meet* conditions exactly! You can prolong pumping efficiency and cut replacement costs!

Take advantage. Send for Bulletin 5502 . . . and specify DARCOVA

DARLING VALVE & MANUFACTURING COMPANY

DARCOVA ®

WILLIAMSPORT 28, PA.

THE ORIGINAL COMPOSITION CUP

WORLD OIL

"Oh! Oh! Here comes the company gusher."

Don't Pamper

Porter: "Carry your bag, sir?"

Gruff old man: "Heck, no, let her walk."

That's Gratitude

Be the first in the office every morning, the last to leave at night, never be absent, always work through your lunch hour, and one day the big boss will call you in and say, "I've been watching your work very carefully, Jones. Just what the hell are you up to?"

Punny

"You can't walk out on me like this," shrieked the circus proprietor to the man, who, for eight years, had allowed himself to be shot out of a cannon twice daily without a word of protest. "Where could I find another man of your caliber?"

Catalog Cannibals

Two cannibals met in a mental institution. One was tearing out pictures of men, women and children from a magazine, stuffing them into his mouth and eating them.

"Tell me," said the other, "is that dehydrated stuff any good?"

Consequences

And then there was the fellow who couldn't quit horsing around until they finally made him a groom.

Convictions

A woman called for jury duty refused to serve because she didn't believe in capital punishment. Trying to persuade her, the judge explained: "This is merely a case where a wife is suing her husband because she gave him $1,000 to pay down on a fur coat and then lost the money in a poker game."

"I'll serve," she said. "I could be wrong about capital punishment."

Can't Please Them All

Two ladies in a car quarreled about the window and at last called the conductor as referee.

"If this window is open," one declared, "I shall catch cold, and will probably die."

"If the window is shut," the other announced, "I shall certainly suffocate." The two glared at each other.

The conductor was at a loss, but he welcomed the words of a man who sat near, who said:

"First, open the window, conductor, that will kill one. Next, shut it. That will kill the other. Then we can have peace."

Two Birds With One Stone

"Stand behind your lover, false woman," thundered the Scotsman, "I'm going to shoot you both."

The Bitter Truth

"Since I got my new car I don't have to walk to the bank with deposits."

"Drive over now, eh?"

"No, I just don't make any."

Confidence

The junior member of a law firm was out of town to try a case. "Let me know as soon as a verdict is reached," counselled the senior partner.

About a week later, the senior partner received a telegram reading: "Justice has triumphed."

Without hesitation the senior partner wired back: "Appeal at once."

...Look for it First in...

Composite Catalog

For more than a generation, COMPOSITE CATALOG has been helping to simplify oil field procurement problems in the field or at the office. In the current edition you'll find detailed information on more than 3,000 oil field products and services—the most useful and complete COMPOSITE CATALOG ever published.

Pioneers of successful magnetic fishing tools and methods

More Magnetic Fishing Jobs Successfully Completed With K & G Tools and Methods than with all other magnetic tools combined...

for satisfaction use

K & G

MAGNETIC FISHING TOOLS
DRILL PIPE JUNK SHOT
ADJUSTABLE CORE BARREL MAGNET

Available in popular sizes from most major fishing tool companies. Be sure to see that it's K & G . . . the only company licensed to manufacture under U. S. Patent No. 2,668,077.

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WORLD OIL

"Get this laugh! He wants a job with a drilling crew!"

A Place of His Own

Wife: "Don't you think it's about time we took Junior to the zoo?"

Husband: "Why? If they want him bad enough, they'll come after him."

Biblical History

All the animals had left the ark except two snakes lying over in a corner.

"Why don't you go forth and multiply?" they were asked.

"We can't. We're adders."

Subject to Overdose

Compliments are like perfume—they should be inhaled, not swallowed.

The Marrying Kind

"They say that people with opposite characteristics make the best marriages."

"That's why I'm looking for a girl with money."

The Clincher

A small wholesaler collected many past-due accounts through the use of the following note on his statements:

"If you will refer to the date of our original invoice, you will note that we have done more for you than your own mother; we have carried you for 14 months!"

RPM Warning

Don't put your tongue in gear unless your brain is turning over.

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Since 1922

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GRAY gives you complete control AT ALL POINTS with complete safety

From casing head to pressure gauge, Gray Multiple Zone Well Head Assemblies are designed for one purpose; Complete control of *your* well.

Design, engineering and construction are based on safety. That's why you get *more strength with less weight.* Through simplicity of design and maximum flexibility, the result is positive, efficient handling of every well control problem — single or multiple zone; high, medium or low pressure at *any* depth. Gray Well Control Systems . . . *complete control gives complete safety.*

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Tool Company

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BUSINESS SERVICE

TO AMERICAN MANUFACTURERS OF OIL FIELD EQUIPMENT:

Well-known German manufacturer of drilling equipment is interested in cooperation with American firms to manufacture its products under license for the European market. Capital investment not required. A query addressed to European Manufacturer, Box 165-W, c/o WORLD OIL, Houston, Texas, will receive our prompt attention.

HELP WANTED

WANTED

Assistant manager, drilling superintendent and petroleum engineer, all in one man, to supervise 2½ year foreign one rig drilling operation. Top salary. Bonus. Send complete resume and references. All replies held strictly confidential. Box 161-W, WORLD OIL, Houston, Texas.

FOR SALE

▪ APPROXIMATELY 820 acre commercial oil and gas lease located in Winkler County, Texas, Section 9 and part of 16, Blk. 27, P.S.L. for sale at $17.50 acre, over 4 years to run on new 5 year lease, no nearby dry holes. Contact Miss Hughes, 2929 Cedar Springs Road, Dallas, Texas, LA 1-9994.

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ACCOUNTANT 20 years diversified oil accounting experience, Foreign-Domestic, Administration-Field, Independent-Major. Last six years Supervisor plant investment and inventory. Available July 1, 1958. Box 156-W, WORLD OIL, Houston, Texas.

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▪ **Delaware Corporations formed and serviced. Inquire without obligation. American Guaranty & Trust Company, 910 West Street, Wilmington, Delaware.**

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Executive type representative-Sales-Promotion-Marketing-Liaison officer. Thoroughly experienced in Latin American markets . . . Excellent contacts abroad . . . Seeking position with American firms planning on opening or expanding foreign operations . . . Fifteen years sales experience . . . here and abroad . . . Fluent Spanish. Knowledge of French and Italian . . . Complete resume on request. Box 164-W, WORLD OIL, Houston, Texas.

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WANTED—drilling superintendent for 2 year foreign operation. Excellent salary. Send complete resume and references. All replies held strictly confidential. Box 162-W, WORLD OIL, Houston, Texas.

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BOOKS

VOLUME REQUIREMENTS FOR AIR AND GAS DRILLING, Gulf Publishing Company, P. O. Box 2608, Houston 1, Texas, by R. R. Angel, $3.

This book presents an expert study of circulation rates required for air and gas drilling. Rates are the minimum necessary to produce velocities in the bottom of the annulus that are equivalent in lifting power to a standard air velocity of 3,000 feet per minute.

Seventy-four easy-to-read curves (full-page size) show you air and gas requirements in standard cubic feet per minute versus depth for a particular drilling rate. Data for gas gravities of 1.0 (air), 0.8 and 0.6 are also included.

Circulation rates for intermediate gravities can be found by interpolation. According to the author, "The solutions that are presented in this book were obtained on a digital computer. The use of this computer saved about six months of slide rule calculating."

OIL—FROM PROSPECT TO PIPE LINE, Gulf Publishing Company, P. O. Box 2608, Houston 1, Texas, by Robert R. Wheeler and Maurine Whited, $2.95.

This is a guidebook for students, mineral owners, investors and oil company personnel. It presents a practical study—written for the layman—on the technical operations of search for, drilling and producing oil.

"Oil From Prospect to Pipe Line" provides a step-by-step explanation of what oil and gas is, how it's derived, how it accumulates and is moved to the earth's surface. The role of the geologist is fully explained. The reader gets a good idea of how the toolpusher, driller and roustabout tackle the tough job of drilling for oil. Who establishes oil prices? Who controls the pipe lines, refineries and marketing facilities? The answers are in the book.

An oil dictionary, abbreviations used in oil reports, typical legal forms and subdivisions of geological eras are included.

PANHANDLE ELECTRICAL LOG SERVICE CATALOG, Panhandle Electrical Log Service, 1407 Ross Avenue, Dallas.

The catalog contains all logs released to Oct. 29, 1957, (inclusive) listed by county, divided between wildcat and field wells, the logs of the Panhandle area of Texas and Oklahoma and the adjoining areas of southeastern Colorado and northeastern New Mexico.

CANADIAN ENERGY PROSPECTS, Royal Commission on Canada's Economic Prospects, British Columbia Electric Company Limited, Vancouver 1, B. C., by John Davis.

The book reviews Canada's energy prospects for the next quarter-century. The document pulls together a good deal of statistical and other information which has not previously been available, to the oil, natural gas and other fuel and power supplying industries in North America.

One particular appendix deals with "Trends in Oil Exploration, Development and Production Costs" in Canada and the U. S.

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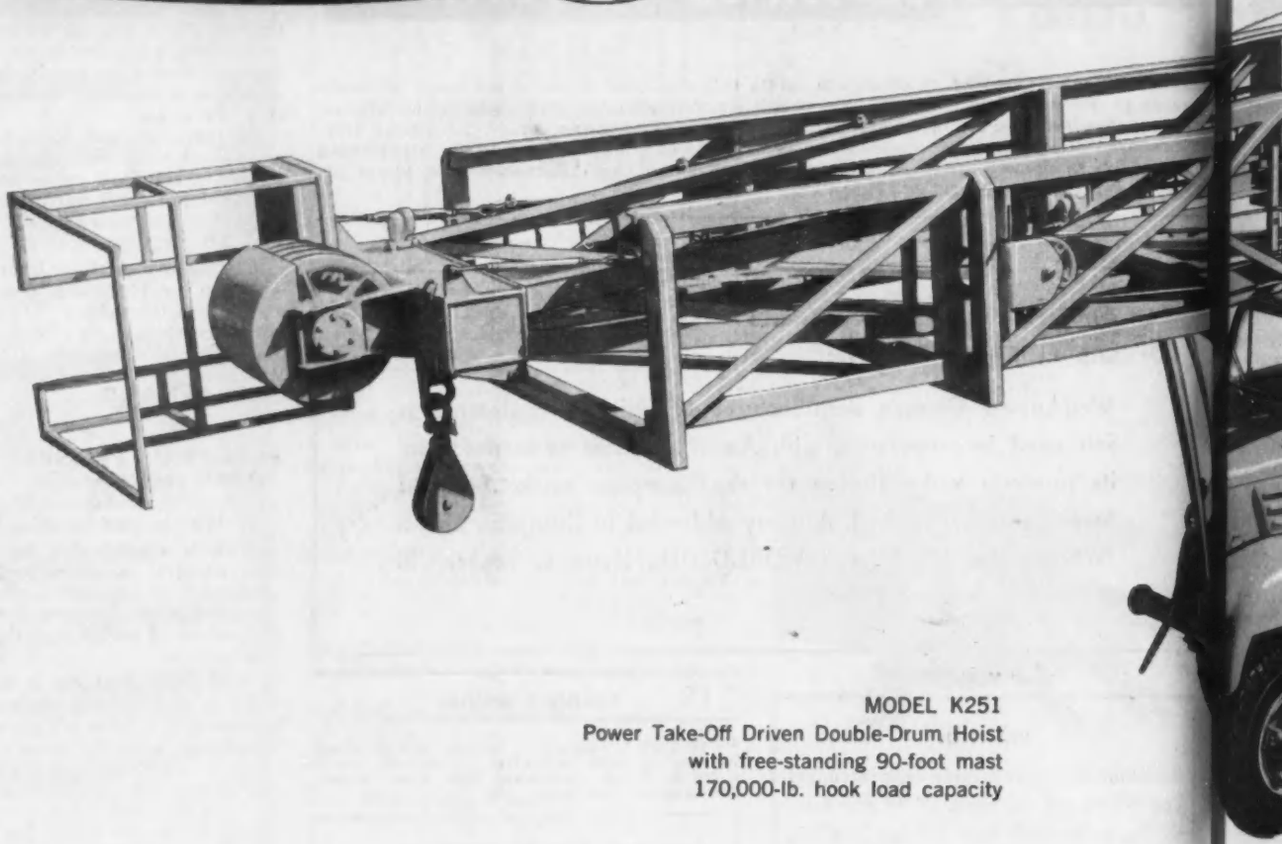


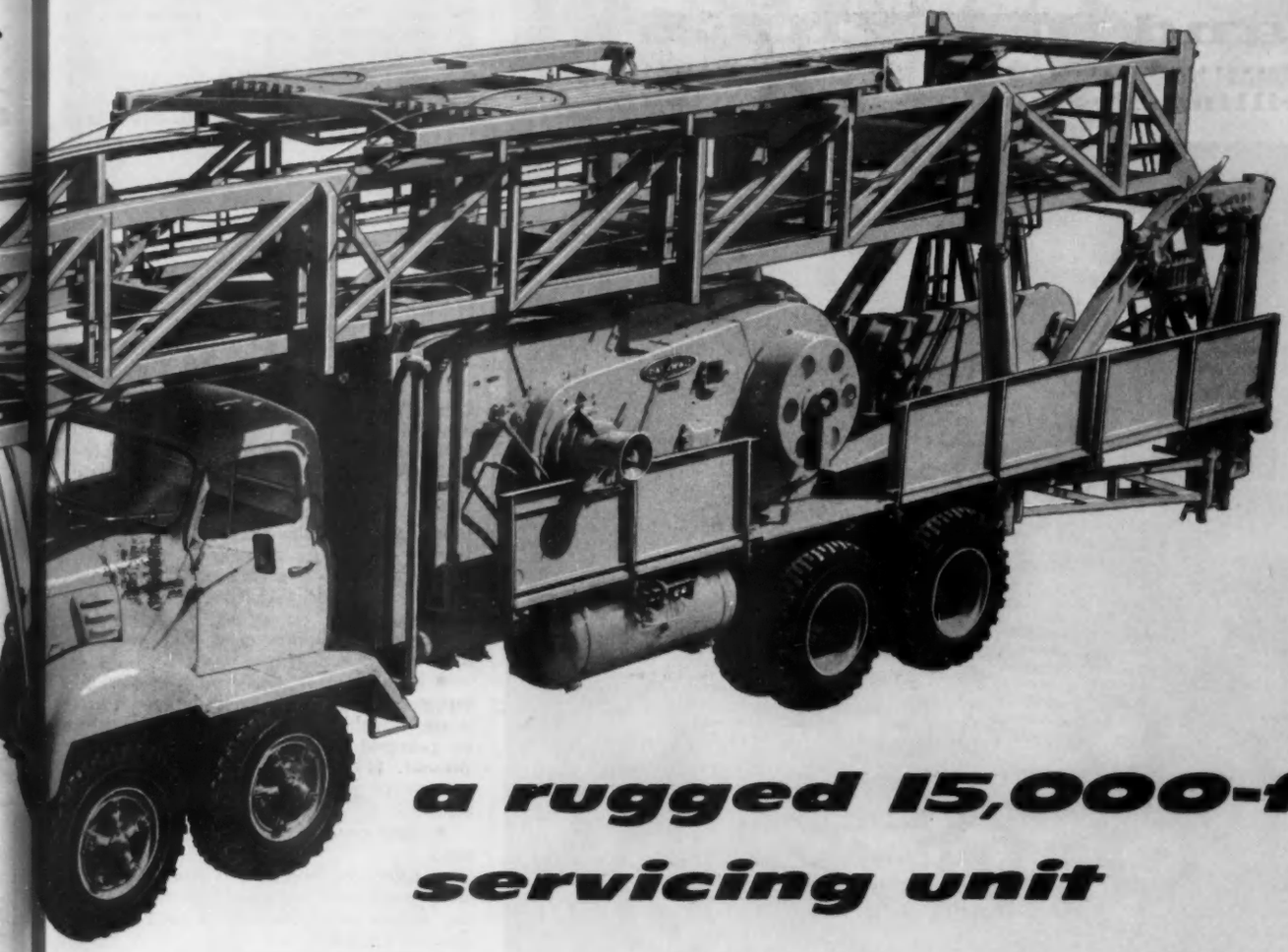
MODEL K251
Power Take-Off Driven Double-Drum Hoist
with free-standing 90-foot mast
170,000-lb. hook load capacity

This outstanding, modern unit meets today's requirements for deep well servicing and workover. The rotary drive, while optional, was engineered as an integral part of the unit. The 90-foot, 170,000-lb. structural mast is designed to rack tubing in doubles and to hang rods in triples. Various heights of single- or double-leg pipe mast are also applicable.

A wide range of truck makes and models will accommodate this Cardwell unit. All controls, including transmission shift, are located at operator's position for efficiency and safety. Recommended depth rating is 15,000 feet with 2½-inch tubing. Unit can utilize up to 350 truck engine horsepower.

available as separate-engine powered double-drum hoist

Cardwell Model K250 is powered by a separate engine, up to 350 H. P. class. It features the same rugged characteristics of Model K251, and can be mounted on a trailer or drive-in type carrier. Ask your nearest Cardwell Representative for full details.



a rugged 15,000-ft. servicing unit

compare these features!

***LARGE DIAMETER HIGH-CAPACITY BRAKES**

Big 44" x 9½" brake flanges provide long life and low maintenance for both flanges and blocks. Cardwell's time-proven brake linkage system provides safe, easy load control for all operations.

***OUTBOARD-MOUNTED DRUM CLUTCHES**

Clutches are the latest improved type available. Fawick Ventilated Construction dissipates heat from frequent engagement and assures minimum maintenance and downtime.

***DOUBLE-END DRUM DRIVE**

Two drum clutches mounted on shaft ends provide 10 forward and 2 reverse speeds to the main drum.

***OIL BATH LUBRICATION**

All chain drives are fully enclosed and oil-bath lubricated for long life and low maintenance.

***15-INCH HYDROMATIC BRAKE**

An optional hydromatic brake is of the double-rotor type for maximum capacity, with friction engaging clutch for fast, smooth operation.

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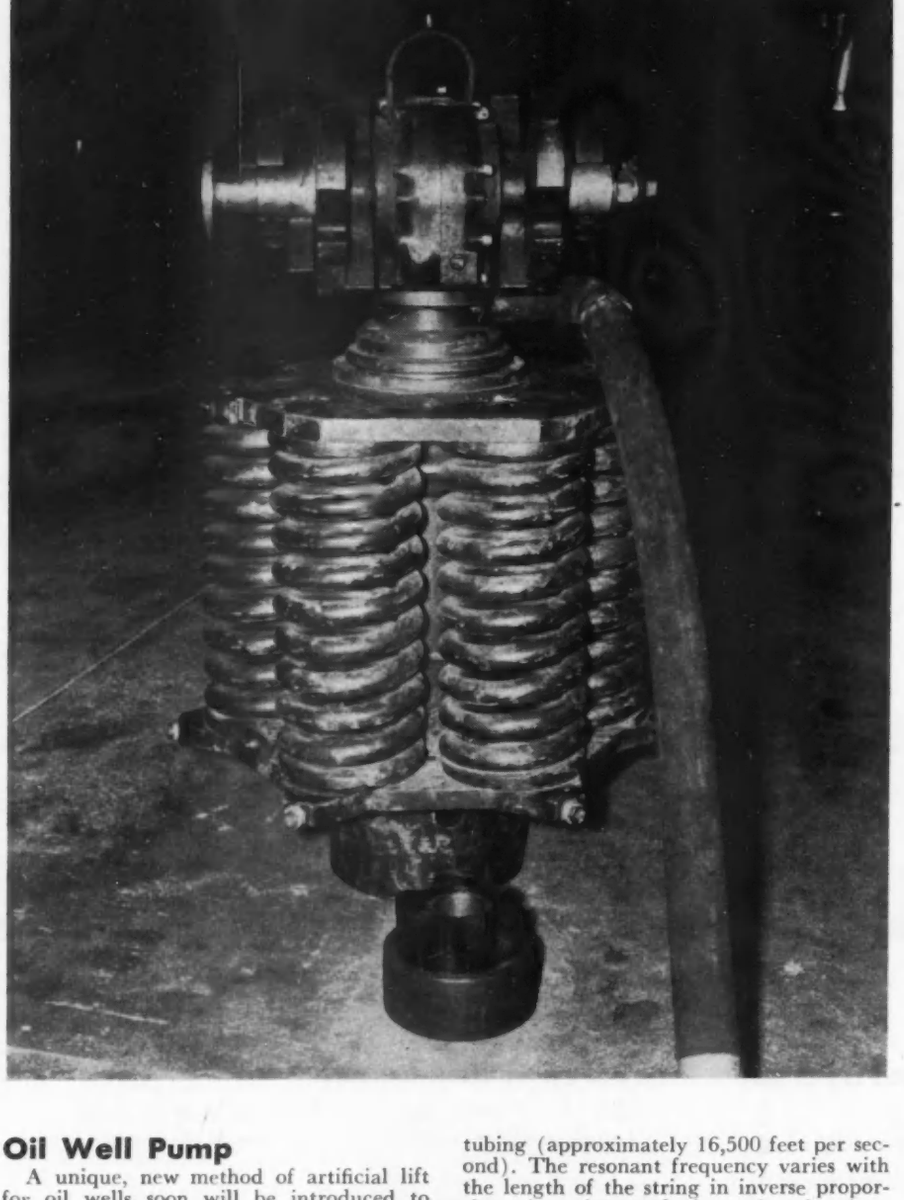
What's New in EQUIPMENT and SERVICES

Drilling - Production - Exploration



Oil Well Pump

A unique, new method of artificial lift for oil wells soon will be introduced to the oil industry by a division of Johnston Testers, subsidiary of Schlumberger Limited. The device, called the Sonic Pump, will provide a simple, durable and cheap means of pumping shallow to medium depth oil wells. The pump has been extensively field tested over the past six years.

The Sonic Pump consists of a tubing string with check valves located in each coupling, a spring mount from which the tubing is suspended, an oscillator to impose vibrations on the tubing and a power source to drive the oscillator. The oscillator is rotated at a rate corresponding to one of the resonant frequencies of the tubing in order to impose vibrations on the string. The resonant frequency (or frequencies) depends upon the length of the tubing string and the speed of sound in tubing (approximately 16,500 feet per second). The resonant frequency varies with the length of the string in inverse proportions since the speed of sound under these conditions is constant. The pump normally operates between 600 and 1,200 strokes (or cycles) per minute.

The stroke of the pump may vary from 3/10 to ½ inch. It can be increased to as much as ¾ of an inch on wells less than 1,500 feet deep. The fluid is impelled upward by the valves in the couplings on the up stroke of the pump. Upward acceleration of fluid is at the rate of from 5 to 10 times the acceleration of gravity, depending on the frequency and amplitude of the stroke. Fluid from a previous stroke will still be rising while the pump is completing the cycle for the next upward stroke.

The tubing string as a whole does not move up and down. Sections of the tubing (including the top and bottom portions) move according to the principle of harmonic motion in an elastic body. At the fundamental frequency the two ends of the tubing move in opposite directions through the cycle while the middle of the string remains relatively motionless. As the frequency is increased by whole number multiples of the fundamental frequency (2, 3, 4, 5 etc.) the number of sections of tubing which are in motion are increased by the whole number multiple plus one. For example, at a frequency four times faster than the fundamental frequency, five sections of tubing are moving. Each section moves in the opposite direction from the adjacent section. Fluid is raised from valve to valve through the tubing to the surface in this manner.

The check valves which convert the vibrational energy of the tubing into pumping action open on the down stroke to pick up fluid from the bottom of the hole or permit fluid impelled upward by the valves below to pass through. On the up stroke the valves close and fluid is passed upward.

An easily installed oil resistant rubber spider with a wear resistant outside guide ring is installed on the tubing string at each coupling and in the center of each joint. These guides prevent lateral vibration of the tubing string which has a tendency to develop under operating conditions. The guide takes but a few seconds to install.

The chief advantages of this new pump are:

- Sand, gyp and mud are easily pumped with no apparent effect on valve parts. Considerable quantities of solids can be pumped if sufficient carrying fluid is present. (On one test well 80 percent by volume of sand was pumped with no ill effects.)
- Any type of prime mover may be used.
- Excellent results have been obtained while pumping low gravity crudes. On test the unit easily pumped 10 to 12 degrees gravity crude.
- Maintenance is at a minimum. The only moving parts on the surface are the spring mount, oscillator, power source and rubber hose connection between tubing and flow line. The oscillator has a one quart oil reservoir which requires checking twice a year.
- The spring mount serves as a foundation. No concrete form is required.
- No counter balance is needed. The stroke of the Sonic Pump is changed by varying the unbalance of the oscillator or the speed of the prime mover.
- No stuffing box is needed. A positive connection is provided between flow line and tubing.
- Initial cost of the Sonic Pump will be at a minimum.
- Check valves installed in the tubing are made of Enrup, an extremely wear resistant material. Very little wear has been noted on these type valves during the extensive testing period.
- Gas as well as liquid can be pumped. Gas lock problems have been eliminated.
- Internal and external tubing wear is reduced since rods are not used.
- The unit will continue to operate efficiently with as many as 50 percent of the check valves inoperative.
- The pump will handle large volumes of fluid.

(This item supplements Johnston Testers, Inc., data on Pages 2781-2804 of the Composite Catalog, 22nd Edition.)

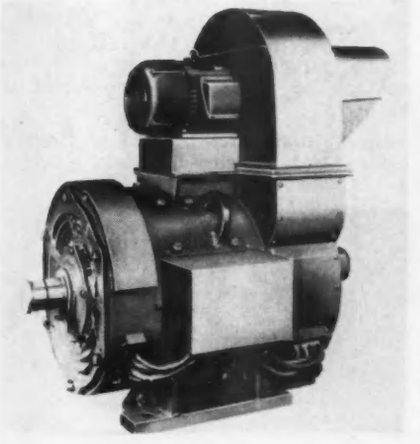
For more data, circle **No. E1** on Readers' Service Card, last page this issue.

Electronic Tachometers

New high-accuracy tachometers, called the PT series, measure speed electronically. Performance Measurements Co. designed these instruments to measure rotational speeds of electrical, hydraulic and pneumatic power systems and internal combustion engines.

Inputs to the tachometers are electrical pulses. Any repeating pulse with a known relationship to the speed being measured can be used. A magnetic pickup close to a rotating part supplies a typical input pulse; magnetic pickups need no mechanical contact.

For more data, circle **No. E2** on Readers' Service Card, last page this issue.



Drilling Rig Drives

New d-c electric drive systems for drillrigs are now available from the Westinghouse Electric Corporation.

There are three combinations of rotating equipment to meet any application whether for land or offshore drilling. The d-c motors have intermittent ratings of 1,600, 575 and 500 hp, and the generators have input ratings of 790, 590 and 270 hp.

One advantage over steam rigs, mechanical rigs and a-c rigs is that the lack of boiler water problem, smooth handling of load, smoother application of power.

For more data, circle **No. E3** on Readers' Service Card, last page this issue.

Fishing Tool

The Nedow Oil Tool Company introduced a new fishing tool to the oil industry. The design of the tool is such that circulation is reversed near the bot-

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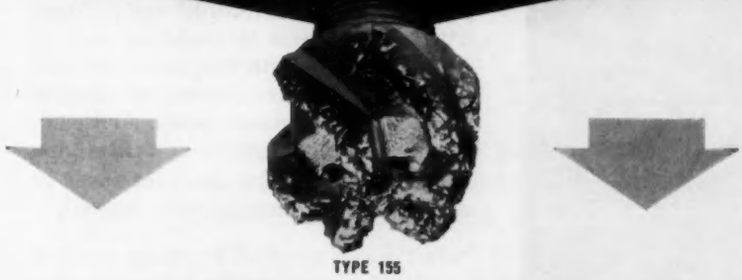

TYPE 155

Continuously renewed multiple cutting edges, in optimum arrangement with tool shape, work contact areas, flushing passages, and other factors combine to make Kinzbach Speedmills highly efficient for downhole metal cutting operations.

Kinzbach Speedmills cut rapidly, leave clean work surfaces, and may be run under severe weight and speed conditions.

Types available for every downhole milling problem.

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HYCALOG

WHAT HYCALOG DID ABOUT THE PASSED-UP SHOW

CONTINUING RESEARCH FOR LOWER COST EXPLORATION

A known producing area in Hidalgo County, Texas, had been passed up in 1954 by several well logging companies — but HYCALOG research engineers weren't satisfied until they discovered why.

Here's what they did:

Transported a CONSOLIDATED ELECTRODYNAMICS mass spectrometer to the well site . . . *the first field application of the spectrometer.*

Worked with BECKMAN INSTRUMENTS in developing a special portable mass spectrometer (the radio frequency analyzer) . . . *the first ever designed specifically for well logging.*

Developed the GAS CHRONOFRAC (patent pending) analytical recorder and included it as part of regular HYCALOG services . . . *at no extra cost.* With this instrument continuously repetitive analyses of samples are run on one-minute cycles. And component analysis is completed in less than two minutes . . . many times the speed of conventional chromatographic analysis.

Now . . . as a result of HYCALOG research . . . *the chance of running past a show has been virtually eliminated.*

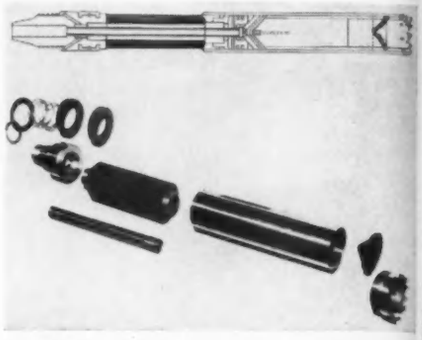
Ask your HYCALOG *representative for information about* GAS CHRONOFRAC *analysis.*

Hycalog, Inc.

505 AERO DRIVE
SHREVEPORT, LOUISIANA

BRANCH OFFICES IN PRINCIPAL OIL PRODUCING AREAS

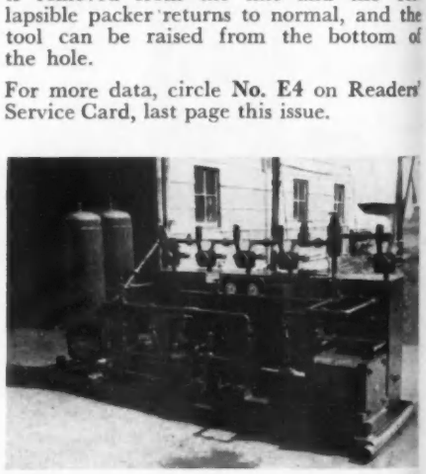
DIAMOND CORING • DIAMOND BITS • WELL LOGGING • CORE ANALYSIS



tom of the hole, and junk is caught up in the mud and moved into the basket of the tool.

In operation the tool is lowered to the bottom of the hole at the end of the drill collar. When the cutter head reaches bottom, adding weight on the cutter causes a collapsible rubber packer to seal off the bottom of the hole. Circulation is through the drill pipe and into the tool, and at a point just below the collapsible packer, the mud is diverted into the annulus of the well and flows down the tool and the walls of the well to the bottom of the hole and back up into the basket of the tool, passing the cutter heads and retaining rubber into the internal basket. At the top of the basket is a filter which stops all of the larger cuttings and junk to retain them in the basket. The mud flows through an internal conductor tube back up the tool to a point near the top where it is diverted back to the annulus on the top side of the packer and is returned to the surface for re-use. When the clean-out at the bottom of the hole is complete, the weight is removed from the line and the collapsible packer returns to normal, and the tool can be raised from the bottom of the hole.

For more data, circle **No. E4** on Readers' Service Card, last page this issue.

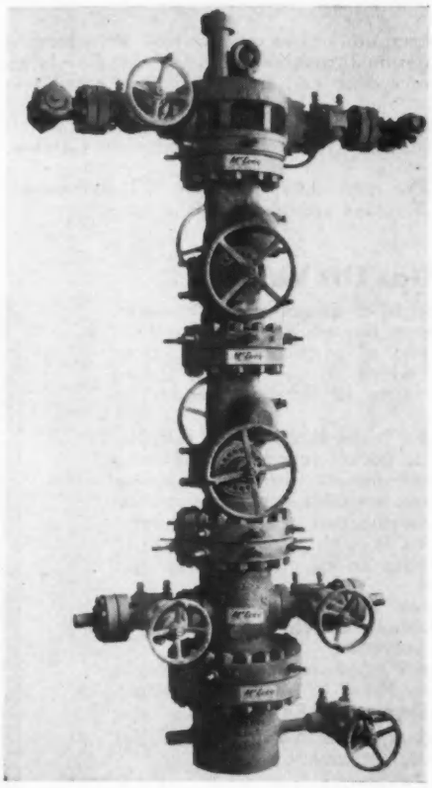


Accumulator Unit

A new 40-gallon accumulator unit, the Wildcat 40, manufactured by the Carthage Tool Company, is equipped with the new Kinzbach M-16 pump, a high pressure, high volume pump designed for extra fast accumulator charging and for extra fast preventer operation in case of accumulator failure.

A compact 10 feet by 5 feet by 3 feet, the complete unit of pumps, accumulators, control equipment and fluid tanks, is skid-mounted for easy handling during transport and at the rig. The Wildcat 40 is completely automatic, is simple to operate and required only 100 pounds air pressure to give all the fluid pressure needed for preventer operation.

For more data, circle **No. E5** on Readers' Service Card, last page this issue.

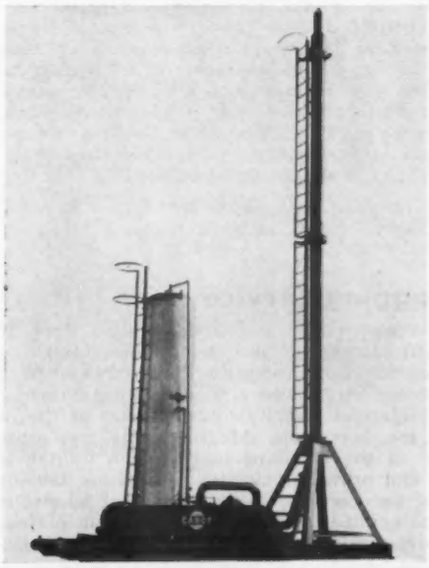


Biggest Dual Tree

The McEvoy Company has just completed a dual completion "christmas tree" capable of handling two strings of 3½-inch tubing in a 9⅝-inch casing. The two strings of 3½-inch tubing constitute one of the largest dual completion trees ever made. From the ground up, the big tree consists of McEvoy Type S casing head with a controlled friction casing hanger; A McEvoy S4H head for suspension of tubing; two McEvoy dual master valves; and a flanged "T" with two 3-inch McEvoy wing valves. The all-purpose intermediate casing head or tubing head is equipped with a pad which may be threaded to accommodate downhole shutoff valves without disturbing other casing annulus outlets.

(This item supplements McEvoy Co. data on Pages 3317-3364 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E6** on Readers' Service Card, last page this issue.

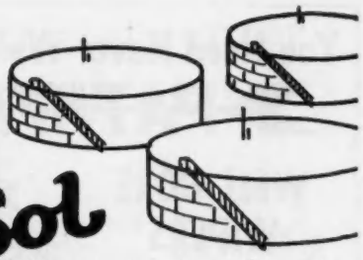


Hydraulic Pumping Unit

The Cabot H36-27 long stroke hydraulic pumping unit has a rated capacity of 36,000 pounds polish rod load and can pump six 27-foot strokes per minute. The stroke length may be reduced by 1-foot intervals to 23 feet.

The H36-27 features such improvements as maximum sim-

RECLAIM TANK BOTTOMS with BrakeSol



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The money you make on reclaimed tank bottoms by using BRAKESOL will be substantially more than the cost of treating . . . including chemical and labor. Safe for use in production, pipeline and refinery equipment . . . Contains no chlorides, sulphides or other halides.
BRAKESOL Treating Engineers have the experience and know-how to do a successful job. Contact them now!

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A Practical GUIDEBOOK To The Oil Industry . . .

OIL

From Prospect to Pipeline

By Robert R. Wheeler and Maurine Whited

1958, 132 pgs., illustrated

Price $2.95

Just published, this book presents a concise account of the technical, economic, legislative and competitive aspects of finding and producing oil. It will prove especially helpful to students considering a career in the oil industry, oil company secretarial and clerical personnel, mineral owners and investors. It is complete with a comprehensive dictionary of oil terms. And, it includes abbreviations used in Oil Reports, typical legal forms used in the oil industry along with subdivisions of Geological Eras.

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From the ROYAL FAMILY of

KING SWIVELS

NEW

30, 40 & 50 KG SWIVELS

All with 3" watercourse

NEW

packing box arrangement eliminates necessity of removing gooseneck and bearing housing to change packing, thus eliminating thread-galling.

SUPERIOR PERFORMANCE

at 100 rpm to 6,200 feet with 2⅞", 3,800 feet with 4½" drill pipe. . . . Perfect for drilling relatively shallow oil wells, the deepest of water wells, workover rigs and slim hole drilling!

NEW!

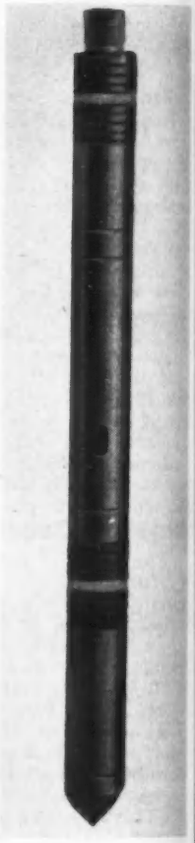
- Wash-pipe packing box arrangement — interchangeable, all 3 sizes.
- Oversize water course (ideal for conventional and reverse circulation)
- Zerk Fitting in stuffing box for simplicity in lubrication of Chevron on V-type packing.

plicity of operation—only one start-up step, minimum counterbalance variation throughout the stroke cycle—large air volume counterbalance tank and simple direct-actuated reversing valve and others.

(This item supplements Cabot Shops, Inc., data on Pages 1109-1115 & 1877-1928 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E7** on Readers' Service Card, last page this issue.

Junior Gas Lift Valves



Two models of junior gas lift valves, for use where limited diameters prohibit employment of standard size valves, have been added to the Harold Brown Company line of oil field production equipment.

One model is the K series, for KB, KC and KT side pocket mandrels. The other is used in conjunction with standard mandrels. Bellows assemblies are interchangeable between the two. The junior size is a 1-inch valve with a 7.50-inch O.D. bellows having an effective area of .300 square inch.

Both valves are available with the recently introduced Harold Brown magnetic ball check valve.

(This item supplements Harold Brown Co. data on Pages 871-873 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E8** on Readers' Service Card, last page this issue.

Plunger Pump

Frank Wheatley Pump and Valve has announced an addition to the company's line of plunger pumps. Designated as the 5P-300, the new 3-inch quintuplex pump operates at 80 hp developing 500 rpm and producing 4,300 bpd at 3,000 psi.

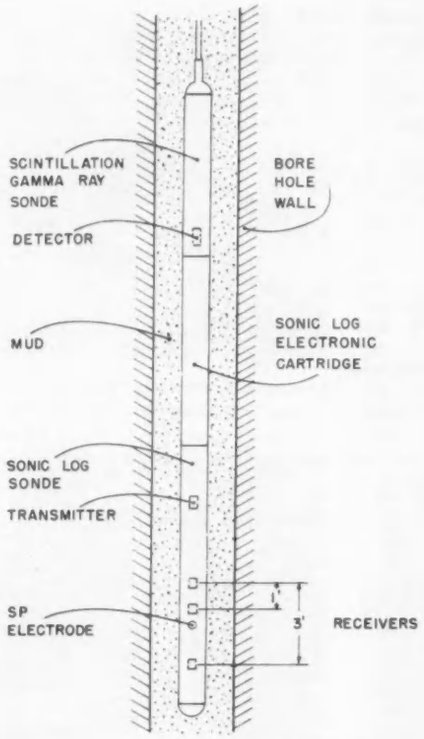
The above performance was achieved by manifolding two additional cylinders to the P-300 triplex pump marketed by the company early in 1957. The new design makes the 3-inch 5P-300 equal in performance to a 4-inch triplex pump at considerable savings in weight and expense.

For more data, circle **No. E9** on Readers' Service Card, last page this issue.

Sonic Logging Service

Recent improvements in instrumentation have turned sonic velocity measurements on sub-surface formations into an important tool for reservoir evaluation. Schlumberger Well Surveying Corporation has introduced a sonic logging service giving accurate and continuous velocity measurements as the instrument is drawn up the bore hole. Measurements are recorded photographically on the standard logging film by the regular field units. The tool provides velocity data, as did the interval measurements of the past, for interpretation of seismic records; but, its principal application is the determination of porosity in the low to medium ranges where other methods are least accurate.

The Schlumberger sonic logging device is based on prototypes developed by Humble Oil & Refining Company. Sound pulses are emitted by the transmitter at the rate of 10 or more per second, and the first arrival of energy at each receiver triggers the response system. The instrument features measurement between two receiving elements rather than between a sound source and a single receiver. This system eliminates error introduced in other experimental and commercial tools by the



time consumed in passage of the sound pulse between the instrument and wall of hole.

(This item supplements Schlumberger Well Surveying Corp. data on Pages 4621-4652-L of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E10** on Readers' Service Card, last page this issue.

Tank Level Detector

Industrial Nucleonics Corporation announces the release of another new product for the process industries. This is the AccuRay Tank level detector-controller.

A major advantage of the AccuRay tank level detector-controller is that no part of the instrument extends into the tank or vessel. It is installed completely external to the tank. Thus it is completely free from fouling by process material and is readily accessible for maintenance. In addition, the instrument can be fail safe for either the high level or low level signal.

For more data, circle **No. E11** on Readers' Service Card, last page this issue.

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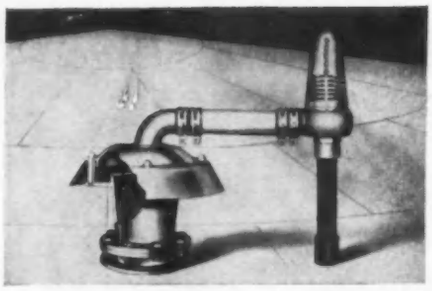


Pilot-Operated Relief Valve

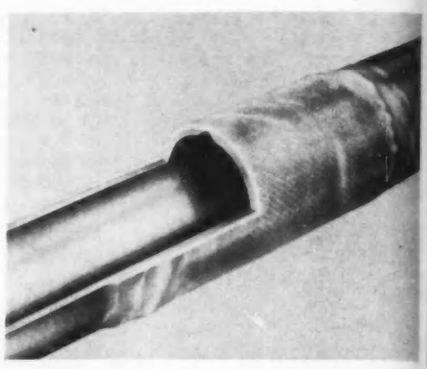
The Oceco Division of the Johnston & Jennings Co. has developed a pilot-operated relief valve for cone roof and other low pressure tanks. It is said to reduce tank breathing to the minimum and increase product savings to the maximum that the pressure and vacuum characteristics of the tank will permit.

These new valves maintain absolute and automatic control of tank breathing. They do not open until the pressure setting of the pilot or the vacuum in the tank reaches the vacuum setting of the valve.

For more data, circle **No. E12** on Readers' Service Card, last page this issue.

Epoxy-Based Sealer

Emergency repairs of metals, plastics, wood, concrete and other materials are quickly made with Homalite 345, an epoxy-based compound recently developed by the Homalite Corporation. The repaired equipment can be back in service within an hour, and the repairs are permanent. Homalite will adhere to any clean, dry material.

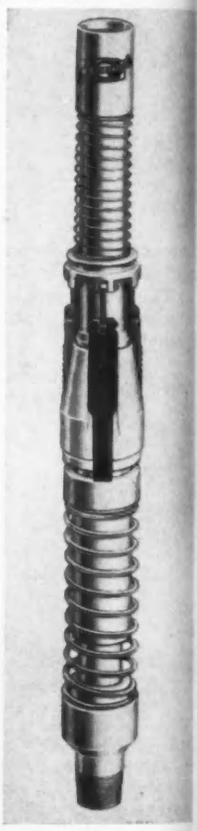


For more data, circle **No. E13** on Readers' Service Card, last page this issue.

Tubing Anchor

The Guiberson Corporation, one of the Dresser Industries, announces availability of a new Type HM2 tubing anchor. The Guiberson HM2 is an automatic tension type tubing anchor which maintains the minimum tension required to prevent tubing buckling and breathing. The anchor is run above the pump and automatically engages the casing when the pressure at the anchor reaches approximately 200 psi. The anchor then moves freely down hole, but prevents upward movement, maintaining the lowest level necessary to prevent tubing buckling and breathing.

(This item supplements The Guiberson Corp., One of The Dresser Industries, data on Pages 2125-2132 of the Composite Catalog, 22nd Edition.)



For more data, circle **No. E14** on Readers' Service Card, last page this issue.

Productimeter Counters

Two Model 5-CS-1-1-R-RP stroke productimeters, made by the Durant Manufacturing Company are installed on a new metering separator for use by oil and gas

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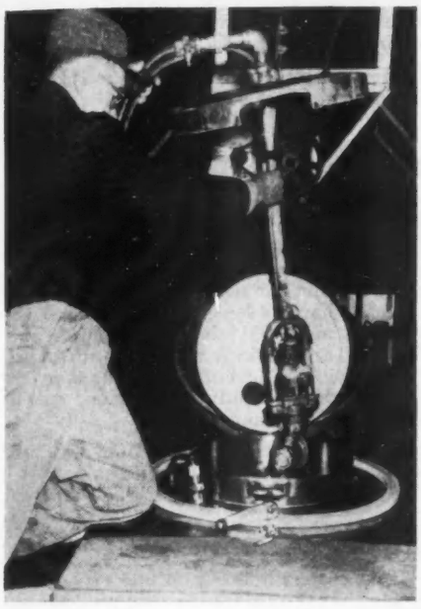
producers. The Oil Metering & Processing Corporation are the designers and manufacturers of this practical metering separator which makes it possible for the first time to separate well fluids within single vessel, and meter each of the components: oil, gas and water.

Model 3OMS-9113-WKMCX is divided into two compartments, one for oil and one for water. The cover of the control housing is open to show the manner in which the two Durant counters are installed. When the oil and water reach a certain point in the vessel, the counters are actuated by a trip mechanism and diaphragm to register the number of times each compartment is filled and emptied.

For more data, circle **No. E15** on Readers' Service Card, last page this issue.



Jet Tank Cleaning

A jet unit for cleaning the inside of tanks, tank cars or tank trucks, of any size or shape more economically and thoroughly than by hand is announced by Sellers Injector Corp. Known as the Sellers rotor jet, this unit has wide application in petroleum and chemical plants.

Operation of the Sellers rotor jet is completely automatic. Personnel need never enter the tank—an important safety feature where toxic or explosive vapors are present. The rotor jet is balanced so that it can be lowered into a tank suspended only by its hose, without additional support. Then, without further attention, it hydraulically scrubs every square inch of tank surface.

For more data, circle **No. E16** on Readers' Service Card, last page this issue.

Surface Caliper Service

Otis Engineering Corp. has announced the availability of its newly-developed surface caliper service which is designed to detect defective joints in either new or used tubing before the pipe is run into a well. The service is especially recommended for surveying tubing that will be set in corrosive, high-pressure wells.

Surveys can be conducted in the customer's pipe yard or on the lease. A special calipering instrument is drawn through the joint to determine the internal condition of the pipe. Pipe can also be cleaned internally and/or drifted if desired. After the entire log is surveyed, an Otis corrosion engineer compiles a detailed, permanent report on the classification of each joint.

For more data, circle **No. E17** on Readers' Service Card, last page this issue.

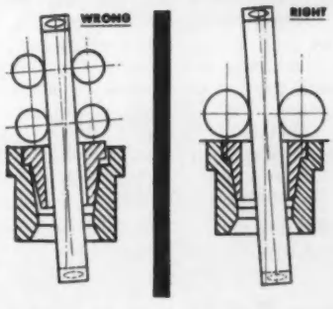
Paraffin Control Method

Brakesol has a method of injecting BrakeSol paraffin treating chemical down the casing on a pumping well for the purpose of treating the oil so that the paraffin will not drop out thereby preventing paraffin accumulations in the well bore, tubing, flow lines and tanks.

This hook-up is designed in such a way as to allow a small stream of oil to be pumped down the casing to carry the paraffin treating chemical. This is accomplished by means of a back pressure regulator which can be adjusted to hold a slightly higher pressure on the tubing than is on the casing. This will maintain a column of oil in the tubing and will give enough pressure to overcome the casing pressure so that the BrakeSol will go down rather than out through the flow line. By extending the flexible tubing down the annulus for at least 10 feet the BrakeSol will be injected below the high velocity area of the casing gas. Either copper or plastic tubing can be used for this purpose.

(This item supplements BrakeSol, Inc., data on Page 870 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E18** on Readers' Service Card, last page this issue.



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New Literature

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Stock Forms Catalog

The Pre-Printed Forms Catalog issued by Gulf Publishing Company contains samples and descriptions of 50 pre-printed forms for oil companies and drilling contractors. The 32-page catalog will be mailed free of charge to anyone requesting it on company stationary.

To get a copy, circle **No. E19** on Readers' Service Card, last page this issue.

Tubular Products Bulletin

Field reports telling how Spang plastic coated tubular products, made by advanced factory processes, are cutting costs by reducing corrosion and paraffin deposition are available from The National Supply Company in a new eight-page, pocket-size booklet.

To get a copy, circle **No. E20** on Readers' Service Card, last page this issue.

Petty Brochure

Petty Geophysical Engineering Company has issued a booklet describing their contribution to the industry. Management, exploration techniques, foreign field operations etc. are described.

To get a copy, circle **No. E21** on Readers' Service Card, last page this issue.

Torque Converter Folder

Torque converters for oil field service are described in a new Bulletin 469 by The National Supply Company. It tells how to drill faster, more efficiently, and make machinery last longer. Operation of National torque converters in improving performance of hoisting, pumping and rotary operation is explained and illustrated. A converter selection chart covers the 100 to 1,000 hp range of six sizes and 17 hydraulic circuits.

To get a copy, circle **No. E22** on Readers' Service Card, last page this issue.

Safety-Relief Valve Data

Detailed information for the ready selection and sizing of all nozzle safety-relief valves manufactured by Farris Engineering Corporation is included in a new specifications catalog just released. The new catalog restricts itself to Farris valves applicable to process piping.

To get a copy, circle **No. E23** on Readers' Service Card, last page this issue.

Vic-Easy Pamphlet

Victaulic Company of America has prepared a new six-page two-color illustrated bulletin describing the Vic-Easy method of quick coupling lightweight pipe or tubing. The bulletin details installation and operating features, explains how the use of lightweight pipe with rolled-grooved ends effects substantial savings and illustrates typical applications in the oil fields, mining and construction.

To get a copy, circle **No. E24** on Readers' Service Card, last page this issue.

Rotary Bulletin

Three new rotaries, the SA-175, LA-175 and A-205 are presented in Bulletin 475 by The National Supply Company. These are the National Type A rotaries of the latest rectangular design. The SA-175 and LA-175 have 17½-inch openings with 44-inch and 53¼-inch spacings. The A-205 is a 20½-inch machine with 53¼-inch spacing. The bulletin features design changes that simplify installation, operation and maintenance.

To get a copy, circle **No. E25** on Readers' Service Card, last page this issue.

Liquid Metering Folder

Two especially accurate and economical meters, the Propeloflo for liquids and the Shuntflo for air, steam or gases are subject of a new bulletin isued by Builders-Providence, Inc., a division of B-I-F Industries, Inc. The six-page bulletin provides photographs, line drawings, cutaway views and technical data tables to supplement the explanatory text.

To get a copy, circle **No. E26** on Readers' Service Card, last page this issue.

Syncro-Spede Folder

The Louis Allis Co., recently announced publication of an eight-page bulletin, No. 1900, on their new "Syncro-Spede," synchronous induction motor. The company claims it is industry's first synchronous induction motor built in the same NEMA fram size as a standard motor of equal horsepower in ratings from 1 to 100 hp.

To get a copy, circle **No. E27** on Readers' Service Card, last page this issue.

Conversion Factor Chart

A reference table for engineers and other executives in wall chart form has been published by Precision Equipment Co. This conversion chart is useful for engineers, shop men and others. Included are common conversions such as inches to centimeters or watts to hp as well as many conversions that are difficult to locate in reference manuals.

To get a copy, circle **No. E28** on Readers' Service Card, last page this issue.